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Preface

This study was conducted by the Geomechanics and Explosion Effects Division (GEED), Geotechnical and Structures Laboratory (GSL), U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS.

The work was jointly sponsored by the U.S. Department of Defense Explosives Safety Board (DDESB), the U.S. Transportation Command, the Explosive Storage and Transport Committee (ESTC) of the British Ministry of Defence, and the U.S. Army Corps of Engineers. The study monitors were Dr. Jerry M. Ward, DDESB, and Mr. M. J. A. Gould, ESTC. The technical guidance and advice provided by Mr. M. M. Swisdak, Jr., Naval Surface Warfare Center/Indian Head Division, and Dr. John Starkenberg, U.S. Army Research Laboratory, are gratefully acknowledged, as is the assistance of Mr. Carl Halsey, Naval Air Warfare Center –Weapons Division, in conducting the test program of Phase 2 at China Lake, California.

Mr. L. K. Davis, GEED, was the principal investigator for this study, assisted by Mr. Max Ford, GEED. LTC Detlev Matheka, German Armed Forces Office, performed the Literature Survey while on assignment to the ERDC Vicksburg site. Mr. Tommy Ray, GEED, supervised the field tests of Phase 2. Ms. Donna Rowland and Ms. Tracey Waddell assisted in the preparation of this report.

During this period, Mr. A. E. Jackson, Jr., was Acting Chief, GEED, and Dr. Michael O'Connor was Director, GSL. Dr. Bryant Mather was Director Emeritus, GSL.

At the time of publication of this report, Dr. James R. Houston was Director, ERDC, and COL John W. Morris III, EN, was Commander and Executive Director.

1 Introduction

Background

Military operations in combat theaters require large amounts of ammunition supplies. The ammunition is normally shipped by truck or rail from a depot or other permanent storage location to an embarkation port, then by ship to a debarkation port, then again by truck or rail to a temporary depot in the combat area. It is then distributed to ammunition supply points (ASP's) or ammunition holding areas (AHA's) for direct access and withdrawal by the combat units.

Military safety regulations (References 1 - 3) require that safety hazard areas be established around each temporary storage location in order to minimize potential casualties and damage from an accidental explosion of one or more storage units. The regulations also provide requirements for minimum separation distances between the storage units so that an accidental explosion of one will not propagate to another. The regulations establish Quantity-Distances (QD's) to define these hazard areas and distances. For example, the Inhabited Building Distance (IBD) defines the hazard distance required to reduce casualties to personnel in buildings and building damage to an acceptable level, and the Intermagazine Distance (IMD) defines the required separation distance between storage units to prevent simultaneous propagation of an explosion.

The QD's are based on three principal factors. The first is the amount of explosives in a given storage unit, called the net explosive weight (NEW), if measured in pounds, or the net explosive quantity (NEQ), if in kilograms. The second factor is related to the type of storage; i.e., open storage, storage in a light structure, in an earth-covered magazine, etc. The third factor is the level of risk that is acceptable, such as a one-percent probability of a casualty for exposed personnel. The risk factors in turn, are used to establish hazard criteria, such as a maximum level of airblast pressure or a maximum number of fragment impacts per unit area.

Requirement

The need for this study was based on several recent developments. In many areas of the world, residential and commercial areas have begun to encroach on military bases or on non-military locations where ammunition may be temporality stored for trans-shipment. It therefore becomes more difficult and costly to

establish large exclusion areas. With the end of the Cold War in the early 1990's, the general public has also become less tolerant of military requirements for large exclusion areas for explosives safety purposes, even on a temporary basis. With the recent changes in military policies that place more emphasis on the speed of deployment, large IMD's reduce the speed and efficiency of handling large amounts of ammunition at temporary storage sites.

The net result of these factors is the need to reduce existing QD requirements for temporary storage whenever and wherever possible. While the QD's given in current regulations are based--as much as possible--on data from experiments and recorded accidents, there are many situations for which reliable technical data are lacking. In these cases, the QD's are based on highly conservative estimates of hazard distances, in accordance with good safety practice. Unfortunately, these conservative estimates may be much higher than the distances that are actually required.

An additional development that may affect QD's for temporary ammo storage is the current trend to transport ammunition in commercial ISO shipping containers, rather than in break-bulk form. This raises additional questions about the applicability of the current QD's for open storage conditions. Of particular importance is the effect of the containers on IMD's if each container is considered to be an individual storage unit. Are the containers strong enough to completely contain the airblast from small explosions? Can they protect crush-sensitive munitions from airblast pressures from nearby explosions? Do the steel walls provide any significant protection against fragments from nearby detonations?

Finally, the recent development of improved barricades, such as the sand-filled Hesco-Bastion wall, have been shown to provide significant protection against propagation between adjacent open storage units. If barricades or other protection schemes are used between ISO containers of ammunition, to what extent could IMD's be reduced to allow closer spacing of ammo containers at a temporary storage site?

The research study, "Quantity-Distances for Ammunition in ISO Shipping Containers," was established by the U.S. Department of Defense Explosive Safety Board (DDESB) to address these issues. Co-sponsors of the project were the U.S. Transportation Command (TRANSCOM) and the Explosives Storage and Transport Committee (ESTC) of the Ministry of Defence, United Kingdom.

Objectives

The overall objective of this study was to provide improved siting guidelines for carrier transfer and temporary storage of ammunition in ISO shipping containers; specifically, to:

- Establish realistic Quantity-Distances for ammunition in ISO containers, and

- Evaluate the effectiveness of propagation barriers for potential further reduction of QD's.

Approach

The study was divided into two parts. Phase 1 was an analytical study designed to develop preliminary "revised" QD's, based on existing information. The specific goals of Phase 1 were to:

a. *Review the state-of-the-art* for establishing QD's for munitions in shipping containers.

b. *Examine the composition* of typical container loads of ammunition.

c. *Develop preliminary "revised" QD's* for ammo containers, based on existing data and the best available hazard prediction methods.

d. *Identify the most critical needs* for additional test data, and

e. *Design a program of experiments* to provide the most needed test data and to verify the revised QD's.

Phase 2 was a program of experiments conducted to provide test data on:

a. The effect of the steel ISO container walls on fragment impact velocities against acceptor munitions,

b. Safe separation distances between ISO containers to prevent propagation by blast pressures, and

c. The performance of sand-filled barricades for preventing propagation at the proposed minimum separation distances between containers.

The following sections of this report describe the procedures and results of Phases 1 and 2.

2 Basis for Analysis

Hardware Descriptions

ISO Containers

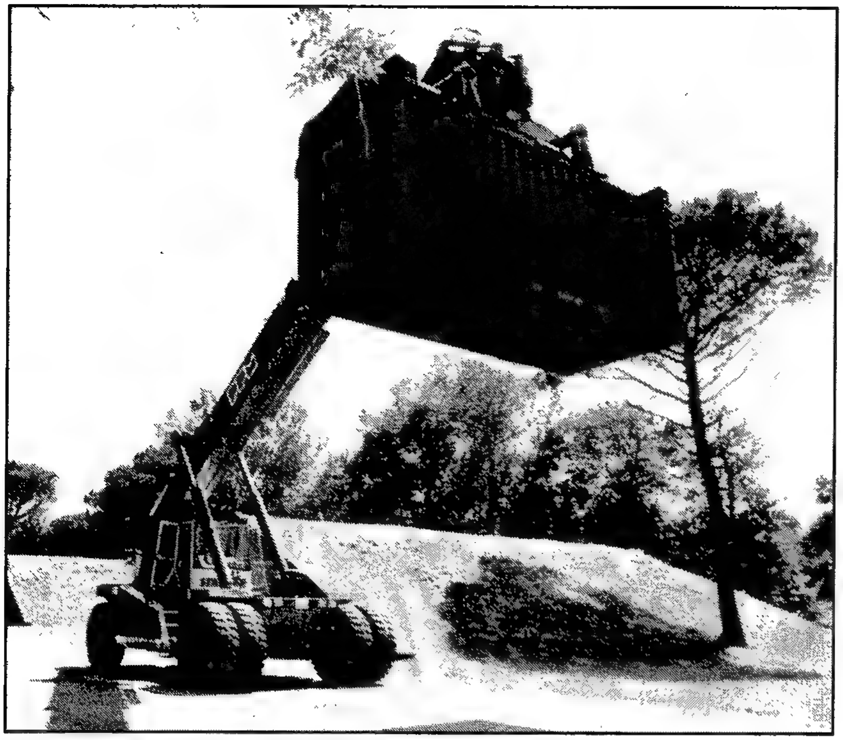
ISO (International Standardization Organization) containers are steel shipping containers used around the world. Their standard design specifications ensure their compatibility with handling equipment, storage areas (such as ship holds), and replacement parts in almost any country. ISO containers are 8 ft (2.44 m) wide and 8 ft high (external dimensions), and come in two lengths; 20 ft (6.6 m) and 40 ft. The top, bottom, and sidewalls are made of corrugated steel panels 1.5 mm thick, joined to steel structural members at the panel intersections. Double-leaf steel panel doors are normally located at one end of the containers. The door opening width and the internal width is 2.35 m (7.65 ft), and the opening height and internal height is approximately 2.12 m (7.0 ft). The 20-ft container has a payload capacity of 18,320 kg. Figure 1 shows a typical 20-ft ISO container, and Figure 2 shows containers used for temporary ammunition storage at U.S. Army camps in Korea.

Munitions

Hazard Classifications. The study was intended to consider, at least in a general sense, all types of ammunition that may be stored or transported in ISO containers. This includes the four principal hazard divisions (HD) in Class 1, as defined by U.S. and NATO explosives safety manuals (References 1 and 3):

- HD 1.1 – Mass detonating items
- HD 1.2 – Non-mass detonating, fragment-producing
- HD 1.3 – Mass fire items
- HD 1.4 – Moderate fire, no blast.

HD 1.1 items (e.g., high explosive (HE)-loaded bombs, 155-mm HE artillery projectiles, AT mines, bulk explosives, etc.) are normally of greatest concern. The term "mass detonating" means that the detonation of a single item, either within the container or nearby, can instantly cause surrounding items to

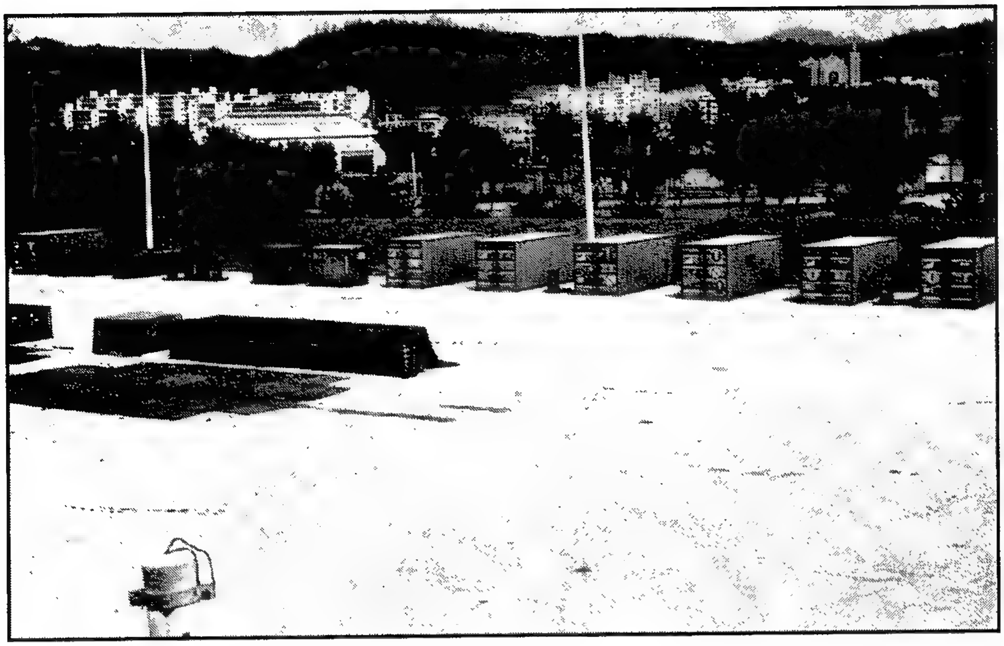


a. Lifting a 20-ft container of ammunition

Max. Gross Weight	20,320 kg 44,800 lbs
Max. Payload	18,320 kg 40,390 lbs
Tare Weight	2,000 kg 4,410 lbs
Inside Cubic Capacity	31.1 cubic meters 1,098 cubic feet
Internal: Height Width Length	2,240 mm 2,352 mm 5,900 mm
Door Opening Height Width	 2,127 mm 2,343 mm

b. Specifications for a 20-ft ISO container

Figure 1. Standard ISO container used for transport and temporary storage of ammunition.



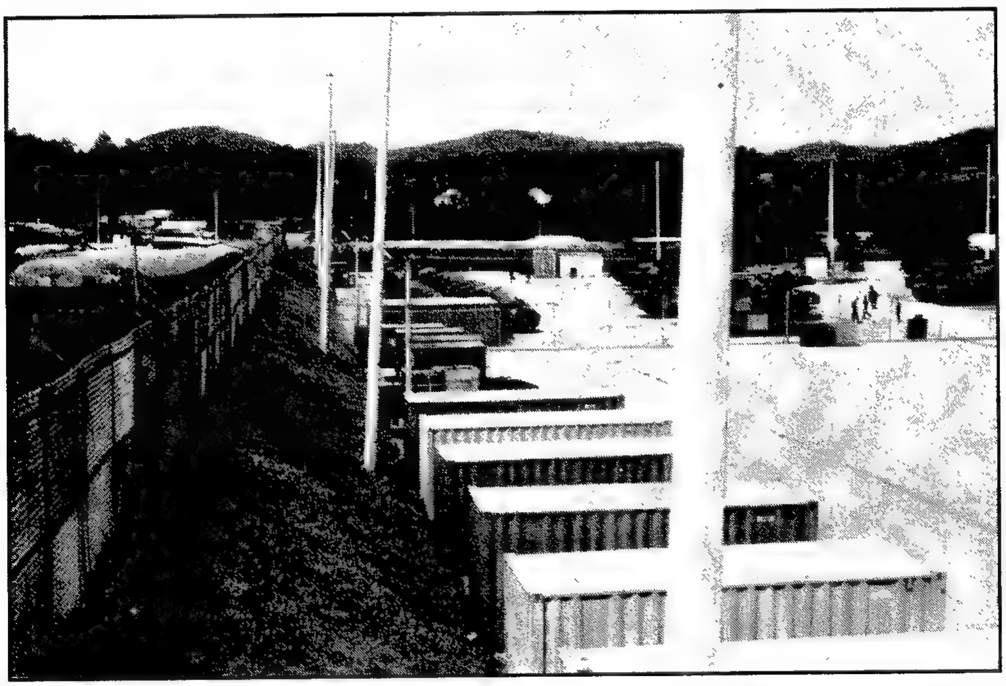


Figure 2. Ammunition storage in ISO containers at U.S. Army camps in Korea

detonate by blast pressure, shock effects, or fragment impacts. This effect is commonly called "propagation" of the original explosion.

HD 1.2 items (e.g, 120-mm HEAT tank ammunition, 30-mm cartridges, etc.) do not explode *en masse*, but produce hazardous fragments when the munitions individually "cook off" (i.e., react, including detonation) in a fire. HD 1.3 items (propellants, flares, smoke rounds, etc.) normally do not detonate, but may rapidly burn *en mass*. HD 1.4 items are relatively innocuous, in that they neither detonate nor burn rapidly.

The hazard classifications for specific munitions in the current U.S. inventories (Army, Navy, and Air Force) are given in the U.S. DoD Joint Hazard Classification System (Reference 4).

Fragmentation Characteristics. For explosives safety purposes, it is important to classify munitions in very general terms according to their ability to produce, or to resist the impact of, heavy fragments. This factor is related to the ratio of the munition's explosive weight to that of its steel casing. Heavy-cased or "robust" munitions typically have explosive-to-case weight ratios less than 1.0, and case thicknesses of at least 0.4 inches (1 cm). Examples are 155-mm projectiles, MK-80 series bombs, etc. Robust munitions produce the greatest fragment hazards, but their heavy cases also provide protection against breakup of the munition under blast and fragment impact loads. Robust munitions may also be more likely to detonate under shock, impact, or crushing loads.

Light-cased or "non-robust" munitions have explosive-to-case weight ratios $\geq$ 1.0, or a case thickness less than 0.4 inches (1 cm). Examples are mines, air-to-air missiles, torpedoes, etc.). The fragment threat from light-cased munitions is limited, because the low mass-to-surface area ratio of their fragments results in high air drag effects and, consequently, limited travel distances and impact forces.

Bare explosive charges, with little or no metal casing at all, represent a third category. These include, for example, demolition explosives, most mine-clearing charges, detonating cord, etc.

Categorization. The U.S., the U.K., and other NATO countries stock many different types of ammunition in each hazard division. Previous practice has been to ship and store munitions of each individual type in bulk; i.e., a single shipping container may contain only pallets of 155-mm HE projectiles, or only boxes of 2.75-in. rockets, etc. To increase the efficiency of ammunition distribution in the combat area, however, there is a growing movement to "pre-configure" ammo loads for specific combat missions. For example, a container carrying a pre-configured load for an artillery unit would contain all ammunition items needed for that mission; projectiles, propellant, fuzes, etc. Similarly, an engineer-configured load may contain demolition charges, shaped charges, Bangalore torpedoes, fuzes, detonating cord, etc.

In this analysis, particular attention was given to the development of QD's for combinations of different munitions, with different hazard classifications, as might be found in containers carrying pre-configured loads. At the time of this study, the U.S. Army has designated 49 specific Strategic Configured Loads (SCL's). Appendix A describes the composition of each of the 49 SCL's, including identification data, the hazard division, and the explosive type and weight for each component.

The United Kingdom (U.K.) has somewhat similar pre-configured ammo loads, but, at the time of this analysis, they are subdivided into only four general mission groups. These are the Infantry Sub-unit (Armored), the Light Gun Sub-unit, the Medium Gun Sub-unit, and the Armored Tank Sub-unit. The load component munitions for each sub-unit are also listed in Appendix B.

Ammunition Packaging. For bulk storage or transport in containers, single-type munitions may be simply stuffed inside containers on pallets (e.g., 155-mm projectiles), in boxes (e.g., 2.75-in. rockets), or in steel packages (e.g., MLRS rockets). Configured loads, on the other hand, are normally stacked according to a specific load plan to ensure efficient packaging arrangements. Figures A1-A4 show load plans for typical examples of U.S. SCL's.

The U.S. Army now uses the Palletized Loading System (PLS), which consists of a platform that can be loaded on or off-loaded from a transport truck using a truck-mounted winch. The Container Roll-in/Roll-out Platform (CROP) is a rolling platform that can be easily rolled into or out of an ISO container. Figure 3 shows an artillery SCL being loaded on a CROP and pushed into a container by a forklift. Figure 4 shows a CROP bulk-loaded with artillery projectiles being removed from a container and loaded onto a transport truck using a PLS.

Guidelines

Sources

The principal source of guidelines for this study was the August 1998 edition of the U.S. "DoD Ammunition and Explosives Safety Standards," DoD 6055.9-STD (Reference 1). Additional information was obtained from the NATO manuals AASTP-1, "Manual of NATO Safety Principles for the Storage of Military Ammunition and Explosives," (Reference 2), and AASTP-2, "Manual of NATO Safety Principles for the Transport of Military Ammunition and Explosives" (Reference 3).

Information on the descriptions and hazard classifications for specific munitions was taken from the U.S. DoD Joint Hazard Classification System (Reference 4). Updated information on Q-D rules for HD 1.2 ammunition was obtained from NSWC Report IHTR 1964, "Proposed Quantity-Distance Rules for Hazard Division 1.2 Ammunition," (Reference 5).

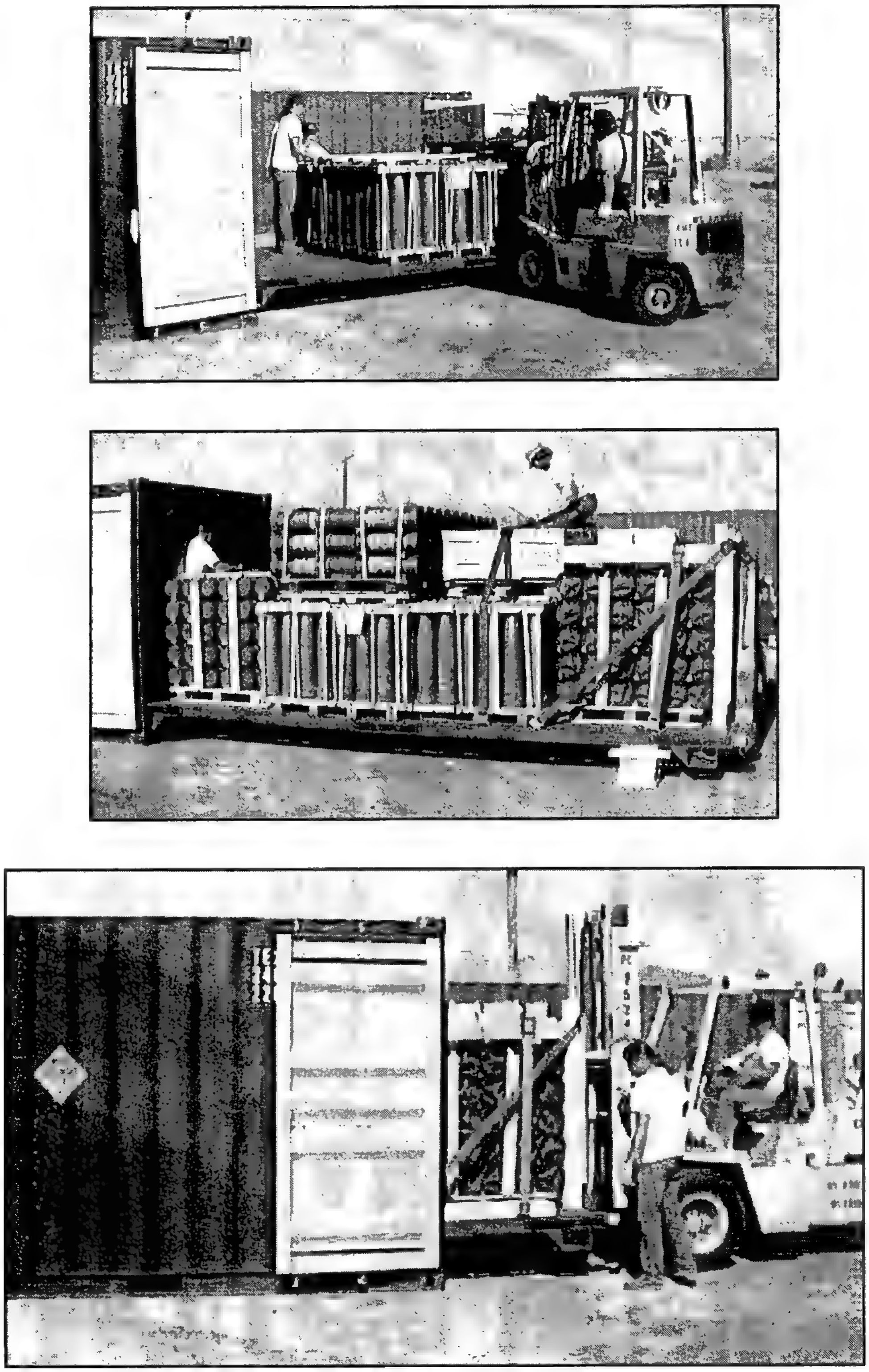


Figure 3. Preparation of a mission-configured load of artillery ammunition and loading into an ISO container

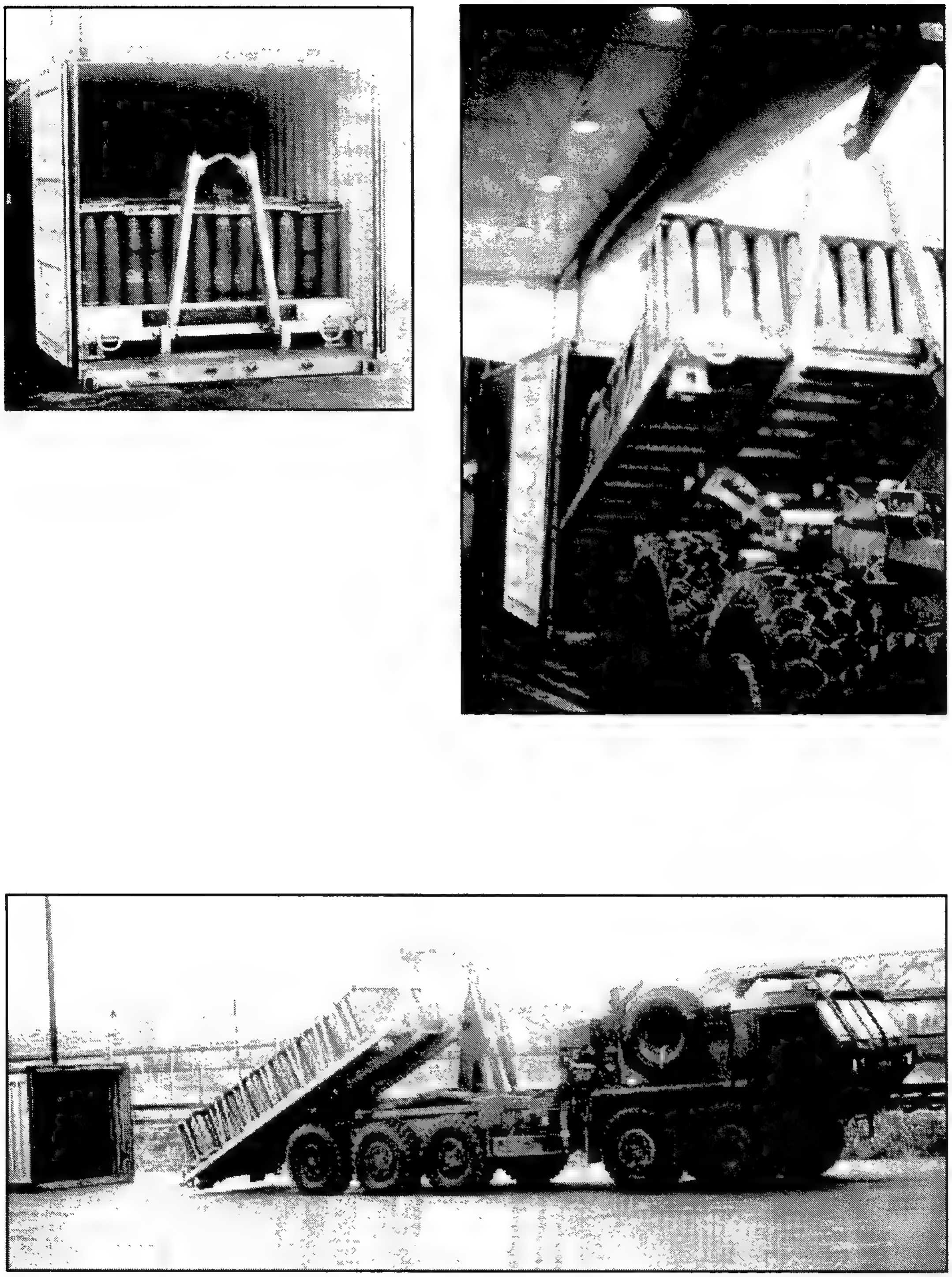


Figure 4. Removing a munition load from an ISO container, using the CROP platform and the PLS loading system

Terminologies

There are a number of terms used in this analysis that are somewhat esoteric, and not commonly used outside the explosives safety field. The more important terms are listed below (more exact definitions are given in Reference 1).

Donor – The single unit of explosive items that initially detonates, in a group of two or more units. The donor unit may be a single round, a single container of munitions, a single magazine, etc.

Acceptors – One or more units of explosive items near a donor that are endangered by the donor detonation.

Propagation – The detonation of an acceptor unit caused by a donor detonation. (Note: In this study, the term is used in reference to prompt propagation, where the airblast from the acceptor detonation is superimposed onto that from the donor, so that the detonations are equivalent to a single event).

NEQ or *NEW* – The net explosive quantity, in kilograms, or net explosive weight, in pounds, of a unit of explosive material. The unit referred to may be a single round, a stack, a container load, a storage area, etc.

Maximum Credible Event (MCE) – The maximum amount of explosive material that would be expected to detonate in a single explosion event. The MCE includes both the donor and acceptors, when prompt propagation of a detonation occurs.

NEW/QD – The portion of the NEW considered in QD calculations; i.e., that would contribute to the MCE in the event of a detonation.

Quantity-Distance (QD) – The distance to which explosion hazards extend from the detonation location, expressed as a function of the quantity of explosive material involved. The principal hazards of concern may be airblast, fragments (primary fragments are from munition casings; secondary fragments or debris are from items, material, or structures around the detonation source), or ground shock. The QD's of importance to this study include:

> *Inhabited Building Distance (IBD)* – The maximum distance (QD) at which there is a significant probability that blast effects damage to buildings may cause serious injury to the building inhabitants, or damage greater than five percent of the building replacement cost.
>
> *Public Traffic Route (PTR) Distance* – The maximum distance at which there is a significant probability of injury to personnel in conveyances along any roadway, railway, or navigable stream used routinely by the general public.

Intermagazine Distance (IMD) – The maximum distance between explosives storage units (e.g., ISO containers of ammunition) at which there is a significant probability of a propagation of a detonation between donor and acceptor units.

Mitigation – The reduction of a QD or hazard distance by some form of protection. Principle protection methods considered in this study include:

Barricade – A barrier structure placed near a donor or acceptor unit to intercept fragments and/or deflect airblast loads. Examples are concrete walls, sand-filled wall structures, etc.

Buffers – Non-mass detonating ammunition located within a storage unit that prevents propagation of a detonation from the one side of the buffer to the other. For example, boxes of HD 1.4 items placed between pallets of HD 1.1 items inside a container.

Shielding – Panels of inert structural material placed around a unit of ammunition to mitigate fragment hazards. For example, the steel wall panels of an ISO container provide some degree of shielding of the container contents.

Assumptions for Analysis

A number of assumptions were required in order to establish criteria for propagation of a detonation between ammunition loads in containers, and for determining hazard distances. The principle assumptions included:

For Donor Loads:

- Only heavy-cased munitions produce fragments of sufficient mass and velocity to cause sympathetic detonation of an acceptor (i.e., propagation).

- Only those rounds on the side of a donor load facing the acceptor will contribute to the fragment threat for IMD calculations.

- If the highest hazard division in a donor unit is HD 1.2, it is assumed that the fragment hazard is from the detonation of one round only. This round is assumed to be on the side of the donor load facing an acceptor container.

- If a donor load containing fragment-producing munitions is buffered on a side (or end) by light-cased munitions or uncased explosives, or by HD 1.3 munitions such as propellant, then there is no fragment hazard in that direction.

For Acceptor Loads:

- A load containing no HD 1.1 items will not sympathetically detonate from the detonation of an adjacent load (unless the loads are essentially in contact with one another).

- A prediction of the probability of a hazardous fragment hit (and detonation) of an acceptor load is based on the vulnerable area (to fragment impact) of the HD 1.1 items in the load.

- An impact kinetic energy of 50 ft-lbs or more is required to cause mechanical damage to a light-cased acceptor munition by fragment impact, and 400 ft-lbs to a heavy-cased munition.

- An acceptor munition will detonate when the donor fragment impact conditions meet the criteria defined by the Jacobs-Rosland formula, as used in the FRAGPROP computer model (see next section).

3 Phase 1a: Quantity-Distance Analysis

Literature Survey

The first undertaking in this study was an extensive survey of the available literature to identify and review previous research efforts related to the objectives of the program. This effort was conducted to extract any information that would be useful to the analysis, and to avoid duplicating any work that had been previously performed.

The Literature Survey was led by LTC Detlev Matheka of the German Armed Forces Office, who was on a temporary assignment to ERDC. Consequently, the survey had access to many explosives safety references for European studies through technical libraries of the German Armed Forces, as well as U.S. sources.

Over 5,000 references were scanned by title, by abstract, or by detailed review. Reference sources included the proceedings of the DOD Explosives Safety Seminars; the DDESB, ERDC, German Federal Armed Forces Office, and other libraries; the Defense Technical Information Center, and other sources. A total of 613 references were selected for inclusion in the listings, and data from over 2,500 explosion tests were tabulated in spreadsheets.

The results of the Literature Survey are contained in a separate, supplemental report (Reference 6) under the Container QD Study. The report consists of two parts. Part 1 describes the survey approach in detail, and lists pertinent data on each item reviewed. The literature search was keyed to specific categories to facilitate access to information needed for a particular analysis. The principal categories were based on the subjects of Donors, Acceptors, QD's, Propagation, Containers, Mitigators, and (major test) Programs. In addition, a large number of search terms are listed to expedite access to references on specific subjects. For example, over 120 munition or explosive types are listed under the category of acceptors, and some 30 types of blast or fragment mitigators (e.g., barricades, buffers, revetments, walls, etc.) are listed under the category of revetments/shields/walls. References from the five main sources are tabulated by title and a reference number. The most relevant references have a full-page description, including a summary paragraph and other pertinent information. Others have only brief descriptions.

Part 2 of the Literature Survey contains the test data tables extracted from the relevant references. The tables are mainly subdivided by the acceptor and donor munition types that were tested, along with their explosive weights and hazard divisions, and the reference numbers of the reports describing the tests.

In spite of the unexpectedly large number of references that were found, the useful information that could be extracted was often limited, for several reasons. In many cases, the data recorded for a test was incomplete (e.g., the donor was identified only as a "projectile"), or the munitions tested were obsolete and have no identified modern corollary, etc., etc. In other cases, however, useful information was obtained, such as the airblast pressure, fragment impact velocity, or flyer plate impact energy required to initiate a specific type of reaction (e.g., detonation, burn, or no reaction) in a particular type of munition.

The information developed from the Literature Survey was used to the fullest extent possible in both the QD analysis (Phase 1) and the design of experiments (Phase 2) for this study.

QD Calculations

The QD's for the 49 SCL's of ammunition in ISO containers were calculated in three stages. First, the "current" QD's were determined based on the current U.S. and NATO safety standards (References 1 and 3). Secondly, "revised" QD's were determined from calculations of the airblast and fragment levels, and the risk of propagation to adjacent containers, that could be expected from each SCL, using the best available prediction models. And thirdly, "reduced" QD's were calculated based on the expected protection levels provided by barricades and other mitigation techniques. Figure 5 is a flow chart illustrating this procedure.

Determination of NEW, NEW/QD and MCE

The first step in defining the QD's for mixed loads of ammunition is to determine the total explosive quantities in each load. This was done for each of the 49 Army SCL's. The net explosive weight (NEW) of each munition item is defined by the Joint Hazard Classification System (JHCS) and Technical Bulletin (TB) 700-2 (Reference 4). The total number of a single item in a SCL is considered as a "component" of the load. For each munition component in each SCL, the Net Explosive Weight (NEW), the NEW for Quantity Distance (NEW/QD), and the Maximum Credible Event (MCE) were determined, according to the NEW of the individual items, the number of items, and the hazard division of that component. In most cases, the NEW/QD is the same as the NEW. There are, however, a few exceptions according to the JHCS.

For HD 1.1 components, the MCE is simply the NEW/QD for each item multiplied by the number of items. For HD 1.2 components, the MCE is normally considered to be the NEW/QD for each item multiplied by 1.5 times

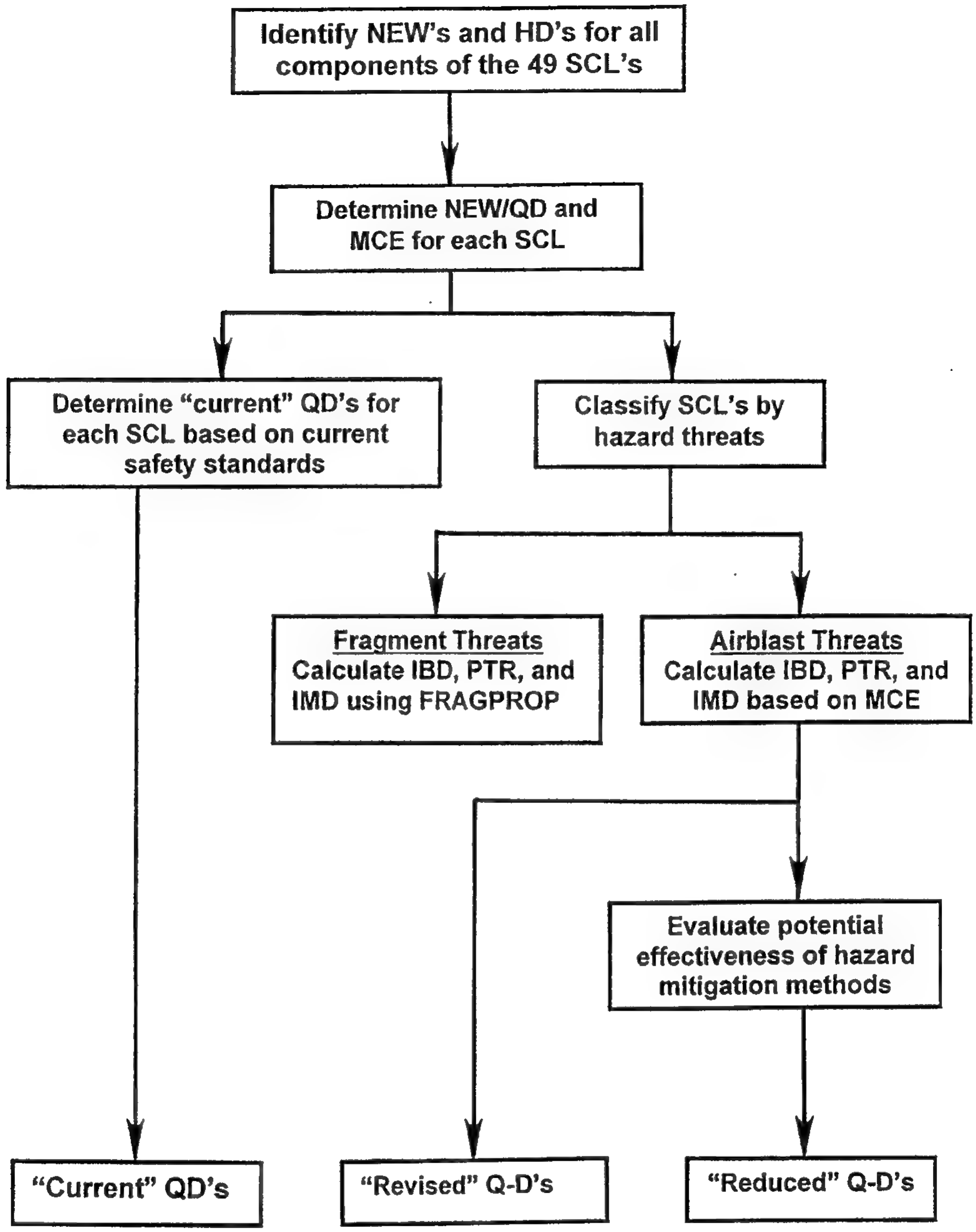


Figure 5. General flow chart for development of Quantity-Distances values for ammunition loads in ISO containers

the number of acceptor items that are required in UN Test 6(b) for hazard classification, unless a smaller number has been demonstrated (see Note below). These MCE's were obtained from the JHCS. For HD 1.3 and 1.4 components, the MCE's for the components themselves are zero. If an item contains HD 1.2 or 1.3 along with the HD 1.1 materials, the weight of the HD 1.2 or 1.3 material is included in the MCE calculation.

The NEW and NEW/QD for an entire load is the sum of those values for each component in the load. The MCE for the load, however, is based on the mixture of hazard divisions that it contains. The MCE of each HD 1.1 component is always included in the total MCE for the load. If any HD 1.2 component is included in a load containing an HD 1.1 component, then the NEW/QD's of the HD 1.2 components are included as part of the MCE for the total load. If there is no HD 1.1, then the MCE value used in this study is equal to one-third of the NEW/QD for all HD 1.2 components (see Note below). The total MCE for a load will include the NEW/QD for HD 1.3 components only if HD 1.1 material is also present. HD 1.4 components are not included in the MCE's.

NOTE: *The use of one-third of the NEW/QD as the MCE for HD 1.2 material in a load is based on experimental data (Reference 5). It has been demonstrated in cook-off tests, where HD 1.2 items were heated in standard bonfire experiments, that approximately one-third of the munitions in a stack will eventually detonate. This is due, in part, to the fact that early detonations in a cookoff sequence will scatter surrounding munitions (including those in containers), which removes many from the heat source. Although the one-third of the munitions which detonate do so over an extended time-period, a conservative approach assumes that the entire one-third could detonate before personnel can escape or adjacent containers can be moved.*

Determination of Current QD's

The "current" QD's were determined from the guidelines given in the current versions of DOD 6055.9-STD and NATO AASTP-1 (References 1 and 3). The QD's of interest are the Intermagazine Distance (IMD), the Intraline Distance (ILD), the Inhabited Building Distance (IBD), and the Public Traffic Route Distance (PTR).

Since each ISO container is treated as separate storage unit in a temporary storage area, the IMD is equivalent to the safe separation distance between containers that is required to prevent propagation. In the current standards, guidelines for IMD values are given in terms of "K-factors", which define a distance as a multiple of the cube root of the MCE. For example, if a magazine with an MCE of 1,000 lb has a K-6 IMD, it must be separated at least 60 ft from another magazine. The separation distance required to prevent damage to munitions in an acceptor container is the same as the PTR. In using the current standards, each individual container was considered to be an above-ground magazine. The QD's were then determined based on the MCE for each SCL. Table 1 provides the "current" QD's for the 49 SCL's as developed on this basis from the U.S. standards, and Table 2 provides "current" QD's based on NATO standards.

NOTE: *Recent calculations performed by the Huntsville District of the U.S. Army Corps of Engineers (Reference 7), using a DDESB-approved analytical procedure, have provided new estimates of fragment distances for several munitions; specifically, the maximum fragment ranges (up to 2,000 ft or more) and the IBD/PTR hazard distances. However, since these changes have not yet (as of this date) been incorporated in revisions to the U.S. or NATO manuals, the "current" QD's given in Table 1 for fragment-producing munitions are based on the July 1999 edition of DoD 6055.9-STD (Reference 1).*

The actual procedures for calculating the QD's for mixed loads of ammunition can be quite cumbersome. To aid in this process, a guide was developed in this analysis to ensure that each step of a uniform procedure was used for each SCL. The guide is given in Table 3.

Determination of Revised QD's

The "revised" QD's are those that were developed from an analysis of each individual SCL and calculated values of the blast effects (i.e., either the airblast or the fragment hazard). The larger QD from these hazards is given as the QD for each SCL.

Fragment Hazards. To develop more realistic QD's for fragment hazards, the FRAGPROP computer model developed by the U.S. Army Research Laboratory (Reference 8) was used to calculate the dispersion, areal density, and velocities of fragments from donor container detonations, the impact velocities and forces against acceptor containers, and residual velocities after the fragments penetrated acceptor container walls. Certain assumptions were required regarding fragment effects, as listed in the previous section. One of these assumptions was that only heavy-cased munitions can produce fragments of sufficient mass and velocity to cause a sympathetic acceptor detonation. SCL loads containing 155-mm M107 or 105-mm HE projectiles were used in the calculations to represent donor fragment sources. The M107 projectile was used to represent HD 1.1 and HD 1.2 heavy-cased acceptor munitions, and the TOW-2B missile warhead was used to represent light-cased acceptors, since the detonation response of these items can be modeled by FRAGPROP. A slight modification was made to the FRAGPROP code to allow for penetration of both the TOW container and the ISO container wall, since FRAGPROP originally allowed for penetration of only a single container thickness.

Figures 6 and 7 show typical results of the FRAGPROP calculations. The plots show the probability of a fragment hit, against an SCL acceptor at a given range, that will cause any of four possible effects:

- **Detonation** of an acceptor round (D)
- Ignition and **burning** of an acceptor round (B) without a high-order detonation

Table 1
Quantity-Distances for U.S. Army Strategic Configured Loads (SCL's) Based on Current U.S. Standards (DoD 6055.9-STD)

LD no.	LOAD NAME	LOAD	NEW lbs	NEW/QD lbs	MCE lbs	IBD ft	PTR ft	IMD ft	IMD-Bar ft
1	ARMOR, 120mm PKG A	1.2.1	4989	4988.8	61	978	587	200	200
2	ARMOR, 120mm PKG B	1.2.1	4813	4008.7	61	942	565	200	200
3	ENGINEER, BREACHING	1.1	34776	9515.4	9515	1250	750	233	127
4	ENGINEER, MICLIC	1.1	10914	10914	10914	1250	750	244	133
5	ENGINEER. DEMOLITION	1.1	13915	8849	8849	1250	750	228	124
6	ENGINEER, VOLCANO MINE	1.1	5227	5227	5227	1250	750	191	104
7	ARTILLERY, 155mm	1.1	3668	3666	3666	1250	750	170	93
8	ARTILLERY, 155mm EX Range	1.1	5438	5436.7	5437	1250	750	193	106
9	ARTILLERY, 155mm Smoke	1.1	4978	4976	4976	1250	750	188	102
10	ARTILLERY, MLRS	1.1	37645	9291	9291	1250	750	231	126
11	INFANTRY,Small Arms	1.4	3881	0	0	100	100	50	50
12	INFANTRY, Misc	1.1	2494	824	824	1250	750	103	56
13	AVIATION, AH-1	1.1	4090	2898.1	2898	1250	750	300	86
14	AVIATION, AH-1	1.1	3372	2507.6	2805	1250	750	300	82
15	GENERAL PURPOSE, SAA	1.1	3013	710.96	711	1250	750	98	54
16	GENERAL PURPOSE, 40mm	1.1	2207	1075	1075	1250	750	113	61
17	BRADLEY, M2/M3	1.1	5413	1458	1458	1250	750	180	68
18	ARMOR, 120mm APFSDS	1.2.1	6614	5969	60	1007	604	200	200
19	ARMOR, 120mm HEAT	1.2.1	6702	6057	61	1010	606	200	200
20	TOW 2A	1.1	1136	1135.9	1136	1250	750	115	63
21	DRAGON/AT-4	1.1	417	417	417	670	402	200	45
22	MORTAR, 4.2 "	1.1	4383	4376	4376	1250	750	200	98
23	ARTILLERY, 155mm DPICM	1.1	4497	4326	4326	1250	750	118	98
24	ARTILLERY, ATACMS	1.1	7400	1640	1640	1250	750	130	71
25	AVIATION, AH-64	1.1	13707	5656	5656	1250	750	300	107
26	AVIATION, AH-1	1.1	3787	2410.2	2410	1250	750	300	80
27	AVIATION, AH-1	1.1	3682	2812.7	2813	1250	750	300	85
28	ENGINEER, CEV/165mm	1.1	6437	4829	4829	1250	750	186	101
29	ENGINEER, MOBILITY	1.1	9307	7811	7811	1250	750	218	119
30	ENGINEER, DEMO	1.1	16240	11228	11228	1250	750	246	134
31	ENGINEER, MINES	1.1	4125	4123	4123	1250	750	176	96
32	ARTILLERY, ADAMS-L	1.2.1	3958	317	45	492	295	200	200
33	ARTILLERY, ADAMS-S	1.2.1	5088	317.27	45	492	295	200	200
34	ARTILLERY, RAAMS-S	1.1	6743	6742	6742	1250	750	208	113
35	ARTILLERY, RAAM-L	1.1	6743	6742	6742	1250	750	208	113
36	ARTILLERY, RAP	1.1	8717	8715	8715	1250	750	227	123
37	ARTILLERY, HE	1.1	6190	6189	6189	1490	894	202	110
38	ARTILLERY, ILLUM	1.3	4482	4479	0	132	132	82	82
39	ARTILLERY, COPPERHEAD	1.1	2194	2192	2192	1250	750	143	78
40	AIR DEFENSE, STINGER	1.1	1142	94	94	1250	750	50	27
41	MORTAR, 120mm	1.1	3040	3040	3040	1250	750	159	87
42	MORTAR, 81mm	1.1	1918	1918	1918	1250	750	200	75
43	MORTAR, 60mm	1.2.2	2626	2596	2596	110	110	69	100
44	105mm Smoke(WP)	1.2.1	2131	2115	40	833	500	200	200
45	105MM, ILLUM	1.2.1	1979	1959	31	820	492	200	200
46	105MM, HE	1.2.1	2810	2798	47	881	529	200	200
47	105MM, HE M760	1.2.1	3541	3529	28	1000	600	200	200
48	105MM, HERA	1.2.1	3890	3855	39	935	561	200	200
49	KIOWA WARRIOR OH-58D	1.1	1568	817	817	1250	750	103	56

Note: IMD-Bar is Inter-Magazine Distance with Barricades.

Table 2
Quantity-Distances for U.S. Army Strategic Configured Loads (SCL's) Based on Current NATO Standards

LD no.	LOAD NAME	LOAD HD	NEQ kg	NEQ/QD kg	IBD m	PTR m	IMD m	IMD-Bar m
1	ARMOR, 120mm PKG A	1.2.1	2263	2263	270	180	63	10.5
2	ARMOR, 120mm PKG B	1.2.1	2183	1818	270	180	59	9.8
3	ENGINEER, BREACHING	1.1	15774	4316	*	*	*	*
4	ENGINEER, MICLIC	1.1	4951	4951	*	*	*	*
5	ENGINEER. DEMOLITION	1.1	6312	4014	*	*	*	*
6	ENGINEER, VOLCANO MINE	1.1	2371	2371	270	180	64	10.7
7	ARTILLERY, 155mm	1.1+	1664	1663	270	180	57	9.5
8	ARTILLERY, 155mm EX Range	1.1	2467	2466	273	180	65	10.8
9	ARTILLERY, 155mm Smoke	1.1+	2258	2257	270	180	63	10.5
10	ARTILLERY, MLRS	1.1	17075	4214	*	*	*	*
11	INFANTRY,Small Arms	1.4	1761	0	2	2	2	2.0
12	INFANTRY, Misc	1.1	1131	374	270	180	35	5.8
13	AVIATION, AH-1	1.1	1855	1315	270	180	53	8.8
14	AVIATION, AH-1	1.1	1529	1137	270	180	50	8.4
15	GENERAL PURPOSE, SAA	1.1+	1367	322.5	270	180	33	5.5
16	GENERAL PURPOSE, 40mm	1.1	1001	488	270	180	38	6.3
17	BRADLEY, M2/M3	1.1	2455	661	270	180	42	7.0
18	ARMOR, 120mm APFSDS	1.2.1	3000	2707	286	187	67	11.1
19	ARMOR, 120mm HEAT	1.2.1	3040	2747	288	189	67	11.2
20	TOW 2A	1.1	515	515.2	270	180	38	6.4
21	DRAGON/AT-4	1.1+	189	189	270	180	28	4.6
22	MORTAR, 4.2 "	1.1	1988	1985	270	180	60	10.1
23	ARTILLERY, 155mm DPICM	1.1+	2040	1962	270	180	60	10.0
24	ARTILLERY, ATACMS	1.1	3357	743.9	270	180	43	7.2
25	AVIATION, AH-64	1.1	1718	1093	270	180	49	8.2
26	AVIATION, AH-1	1.1	1718	1093	270	180	49	8.2
27	AVIATION, AH-1	1.1	1670	1276	270	180	52	8.7
28	ENGINEER, CEV/165mm	1.1	2920	2190	270	180	62	10.4
29	ENGINEER, MOBOLITY	1.1	4222	3543	327	214	73	12.2
30	ENGINEER, DEMO	1.1	7366	5093	*	*	*	*
31	ENGINEER, MINES	1.1	1871	1870	270	180	59	9.9
32	ARTILLERY, ADAMS-L	1.2.1	1795	144	270	180	25	4.2
33	ARTILLERY, ADAMS-S	1.2.1	2308	143.9	270	180	25	4.2
34	ARTILLERY, RAAMS-S	1.1	3059	3058	304	199	70	11.6
35	ARTILLERY, RAAM-L	1.1	3059	3058	304	199	70	11.6
36	ARTILLERY, RAP	1.1+	3954	3953	346	226	76	12.6
37	ARTILLERY, HE	1.1+	2808	2807	291	191	68	11.3
38	ARTILLERY, ILLUM	1.3	2033	2031	270	180	61	10.1
39	ARTILLERY, COPPERHEAD	1.1	995	994	270	180	48	8.0
40	AIR DEFENSE, STINGER	1.1	518	43	270	180	18	3.0
41	MORTAR, 120mm	1.1	1379	1379	270	180	53	8.9
42	MORTAR, 81mm	1.1	870	870	270	180	46	7.6
43	MORTAR, 60mm	1.2.2	1191	1177	270	180	51	8.4
44	105mm Smoke(WP)	1.2.1	966	959	270	180	47	7.9
45	105MM, ILLUM	1.2.1	898	888	270	180	46	7.7
46	105MM, HE	1.2.1	1275	1269	270	180	52	8.7
47	105MM, HE M760	1.2.1	1606	1601	270	180	56	9.4
48	105MM, HERA	1.2.1	1765	1749	270	180	58	9.6
49	KIOWA WARRIOR OH-58D	1.1	711	370	270	180	34	5.7

Note: IMD-Bar is Inter-Magazine Distance with Barricades.

Table 3
Guide for Determining Quantity-Distances for Mixed Ammunition Loads

1. **Load Hazard Division (HD)** The HD for an ammo load is the same as that of the load component[a] that has the most restrictive HD (HD 1.1, 1.2.1, 1.2.2, 1.3, or 1.4) according to the Joint Hazard Classification System (JHCS) (Reference 4).

2. **NEW - Net Explosive Weight** The NEW of an ammo load is the sum of the component NEW's (item NEW times the number of that item).

3. **NEW/QD - Net Explosive Weight for Quantity-Distance computations**
   a. For HD 1.1 items – use NEW from JHCS
   b. For HD 1.2.1 items – use NEW from JHCS (use largest value)
   c. For HD 1.2.2 items – use NEW from JHCS
   d. For HD 1.3 items – use NEW from JHCS
   e. HD 1.4 items are considered inert and are **not included in any NEW/QD** determinations
   f. For combinations of HD 1.1 and 1.2 (1.2.1, 1.2.2, and/or 1.2.3) – use the total NEW of all items
   g. For combinations of HD 1.1 and 1.3 – use the total NEW of HD 1.1 and 1.3, or 1.1 and the HE equivalence (from JHCS) of 1.3
   h. For combinations of HD 1.2 and 1.3 – use the NEW of HD 1.2 or 1.3; whichever gives the greater hazard distance (separately)
   i. For combinations of HD 1.1 and 1.2 and 1.3 – use the total NEW of all items
   j. For combinations of different HD 1.2 subdivisions (1.2.1, 1.2.2, and/or 1.2.3) – use the NEW for the subdivision that gives the greatest hazard distance.

4. **MCE - Maximum Credible Event**
   a. The MCE for a specific HD 1.2 item is the NEW/QD of a single item plus one-half the number of items required for UN Stack Test 6(b).
   b. Loads containing HD 1.1 components – the MCE is the NEW/QD for the entire load
   c. For HD 1.2 or 1.2 and 1.3 – use the MCE for HD 1.2 items (from JHCS)[b]
   d. If load contains more than one 1.2 component, use the larger MCE.

5. **IBD - Inhabited Building Distance**
   a. For HD 1.1 – use IBD from Table 9.1 or Table 9.2 in DOD 6055.9-STD
   b. For HD 1.2.1 – use IBD from Table 9.6A
   c. For HD 1.2.2 – use IBD from Table 9-7
   d. For HD 1.3 – use IBD from Table 9-10
   e. For combinations of HD 1.1 and 1.2 (1.2.1, 1.2.2, and/or 1.2.3) – consider the total NEW as HD 1.1, and then as 1.2, and use the greater IBD
   f. For combinations of HD 1.1 and 1.3 – consider the total NEW/QD of HD 1.1 and 1.3 (or HE for equivalence of 1.3 from JHCS) as HD 1.1
   g. For combinations of HD 1.2 and 1.3 – determine IBD for HD 1.2, and 1.3 components separately, then use the greater distance
   h. For combinations of HD 1.1 and 1.2 and 1.3 – consider the total quantity as HD 1.1, as 1.2, and then as 1.3. Use the greatest distance.

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[a] A load component is the total number of items of a single type; e.g., 48 rounds of M107 projectiles (DODIC No. D544) is a single component.

[b] It is assumed that HD 1.3 can only contribute if initiated by an HD 1.1 component

6. **PTR - Public Traffic Route Distance**
   a. For HD 1.1 – use 60% of IBD
   b. For HD 1.2.1 – use PTR from Table 9.6A
   c. For HD 1.2.2 – use PTR from Table 9.7
   d. For HD 1.3 – use PTR from Table 9.10
   e. For combinations of HD 1.1 and 1.2 (1.2.1, 1.2.2, and/or 1.2.3) – consider the total quantity as HD 1.1 and then as 1.2, and use the greater IBD
   f. For combinations of HD 1.1 and 1.3 – consider the total NEW of HD 1.1 and 1.3 (or HE equivalence of 1.3 from JHCS) as HD 1.1
   g. For combinations of HD 1.2 and 1.3 – determine IBD for HD 1.2 and 1.3 components separately, then use the greater distance
   h. For combinations of HD 1.1 and 1.2 and 1.3 – consider the total quantity as HD 1.1, then as 1.2 then as 1.3. Use the greatest distance of these.

7. **IMD - Intermagazine Distance, Unbarricaded**
   a. For HD 1.1 – use IMD from Table 9.5 of DoD 6055.9-STD
   b. For HD 1.2.1 – use IMD from Table 9.8 (for light, above-ground structures)
   c. For HD 1.2.2 – use IMD from Table 9.8
   d. For HD 1.3 – use IMD from Table 9.10
   e. For combinations of HD 1.1 and 1.2 (1.2.1, 1.2.2, and/or 1.2.3) – consider the total quantity as HD 1.1 and then as 1.2, and use the greater IMD
   f. For combinations of HD 1.1 and 1.3 – consider the total NEW of HD 1.1 and 1.3 (or HE equivalence of 1.3 from JHCS) as HD 1.1
   g. For combinations of HD 1.2 and 1.3 – determine IMD for HD 1.2 and 1.3 components separately, then use the greater distance
   h. For combinations of HD 1.1 and 1.2 and 1.3 – consider the total quantity as HD 1.1, as 1.2, and as 1.3, then use the greater distance

8. **IMD-BA - Intermagazine Distance, Barricaded**
   a. For HD 1.1 $KW^{1/3}$ – use $KW^{1/3}$, where W is the NEW/QD and K is found in Table 9.5 of DoD6055.9-STD
   b. For HD 1.1.2 – use IMD-BA from Table 9.8
   c. For HD 1.2.2 – use IMD-BA from Table 9.8
   d. For HD 1.3 – use IMD-BA from Table 9.10
   e. For combinations of HD 1.1 and 1.2 (1.2.1, 1.2.2, and/or 1.2.3) – consider the total NEW as HD 1.1 and then as 1.2, and use the greater IMD
   f. For combinations of HD 1.1 and 1.3 – consider the total NEW/QD of HD 1.1 and 1.3 (or HE equivalence of 1.3 from JHCS) as HD 1.1
   g. For combinations of HD 1.2 and 1.3 – determine IMD for HD 1.2 and 1.3 components separately, then use the greater distance
   h. For combinations of HD 1.1 and 1.2 and 1.3 – consider the total NEW as HD 1.1, as 1.2, and as 1.3, then use the greatest distance

9. **ILD - Intraline Distance**
   a. For HD 1.1 – use ILD from Table 9.3 of DoD 6055.9-STD
   b. For HD 1.2.1 – use ILD from Table 9.6A
   c. For HD 1.2.2 – use ILD from Table 9.7
   d. For HD 1.3 – use ILD from Table 9.10
   e. For combinations of HD 1.1 and 1.2 (1.2.1, 1.2.2, and/or 1.2.3) – consider the total NEW as HD 1.1 and then as 1.2, and use the greater ILD
   f. For combinations of HD 1.1 and 1.3 – consider the total NEW/QD of HD 1.1 and 1.3 (or HE equivalence of 1.3 from JHCS) as HD 1.1
   g. For combinations of HD 1.2 and 1.3 – determine ILD for HD 1.2, and 1.3 components separately, then use the greater distance
   h. For combinations of HD 1.1 and 1.2 and 1.3 – consider the total NEW as HD 1.1, as 1.2, and as 1.3, then use the greatest distance.

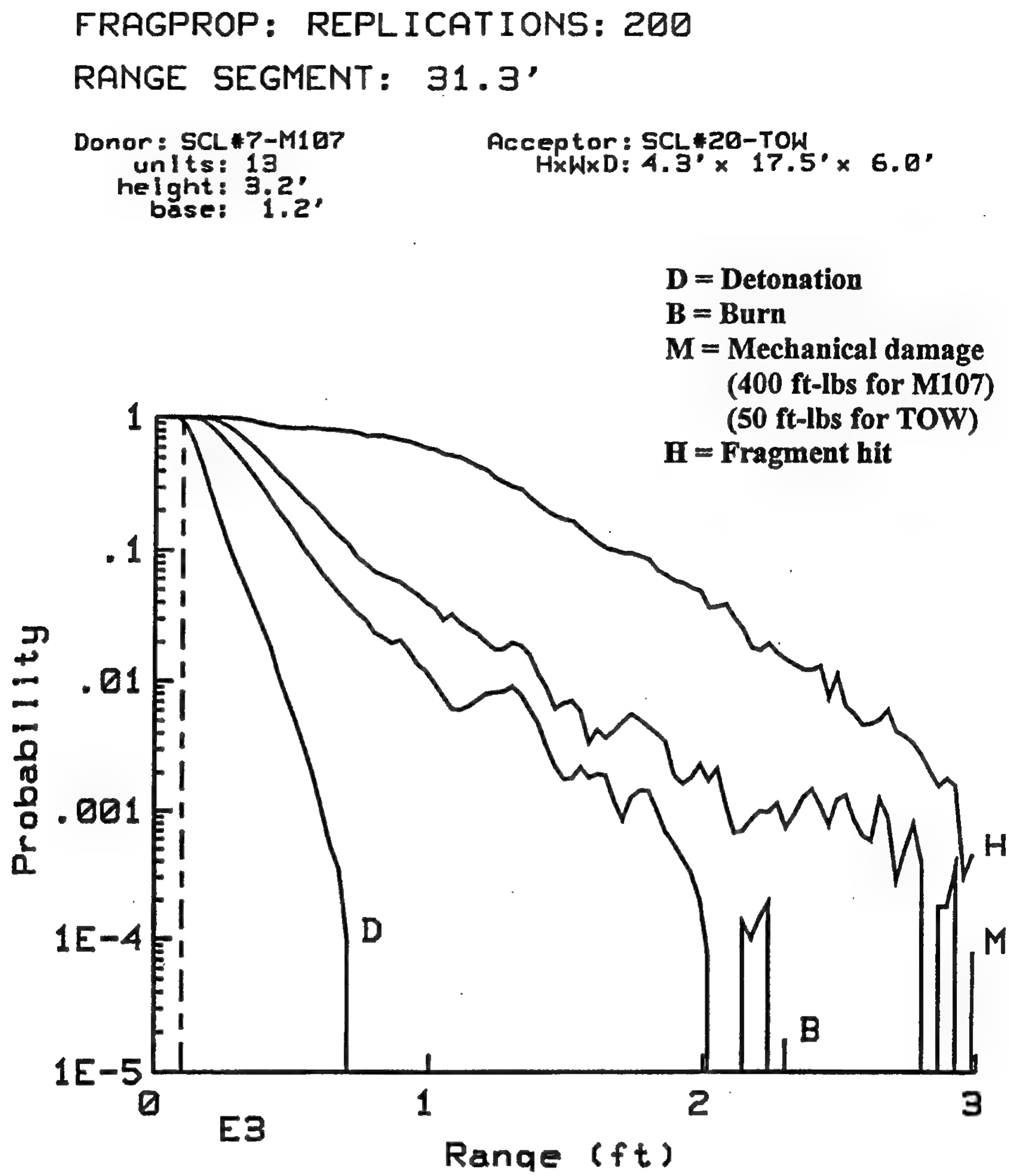


Figure 6. Results of FRAGPROP calculations of the probabilities of different effects from 155-mm M107 (SCL No. 37) donor fragment impacts against TOW-2 missile (SCL No. 20) acceptor loads in the open (i.e., not in containers).

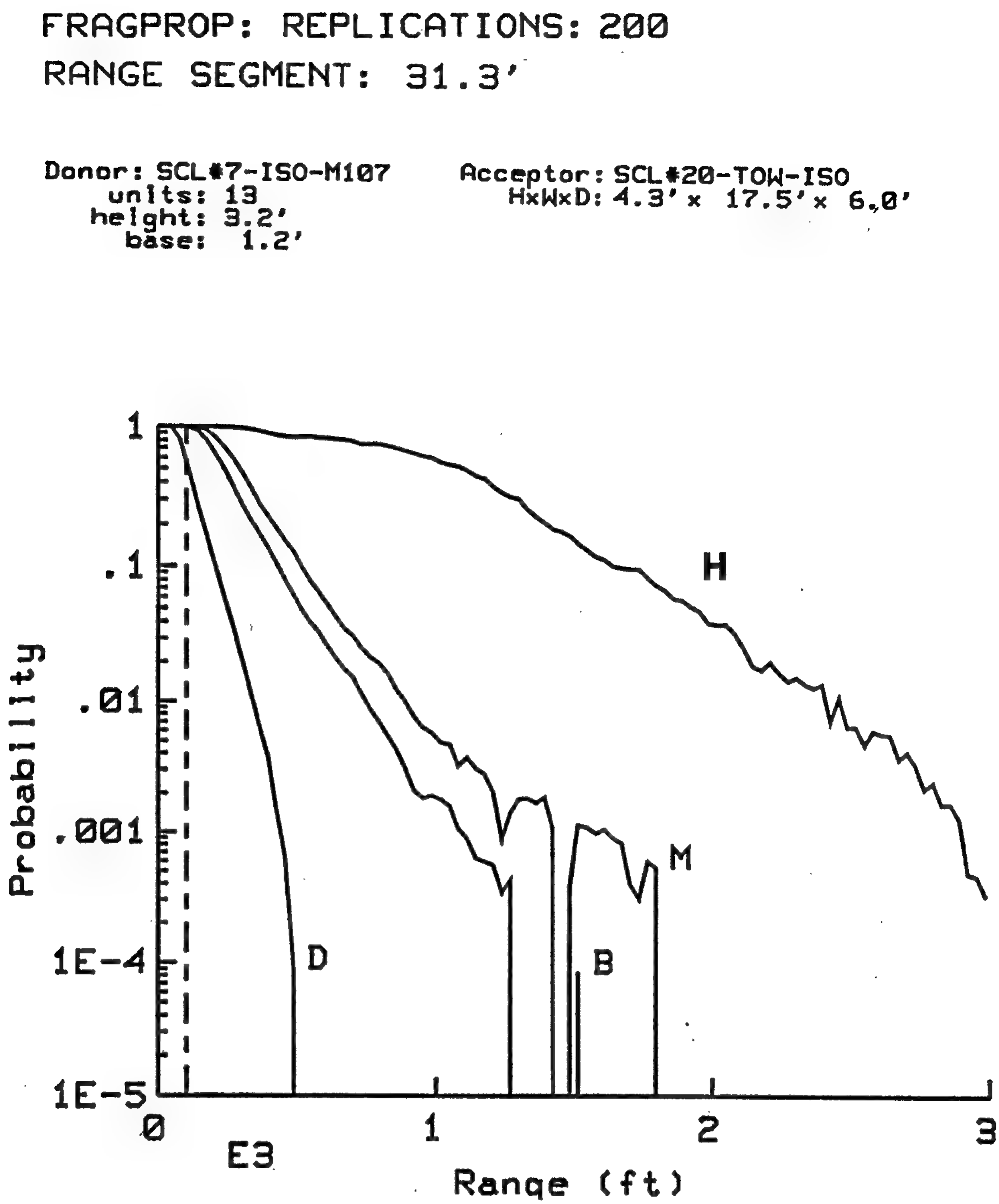


Figure 7. Results of FRAGPROP calculations of the probabilities of different effects from 155-mm M107 (SCL No. 37) donor fragment impacts against TOW-2 missile (SCL No. 20) acceptor loads in containers.

- Mechanical **damage** to an acceptor (M) without detonation or burning

- A hit (H) with **no significant damage**

The donor in the calculations shown in Figures 6 and 7 was SCL No. 37, which contains 24 pallets (192 rounds) of 155-mm HE-loaded M107 projectiles. In accordance with the assumptions detailed earlier, only those rounds on the side of the donor facing the acceptor (a total of 13 rounds) contributed to the fragment threat.

The acceptor in the calculations shown in Figures 6 and 7 was SCL No. 20, containing seven pallets (84 rounds) of TOW-2B missiles. The dimensions of the packaged load for SCL No. 20 (as given in Appendix A) were used to determine the "worst case" presented area to the donor fragments.

Figure 6 shows these probabilities of the different damage effects for an SCL No. 20 acceptor in an open storage situation. Figure 7 shows the probabilities for the same SCL inside an ISO container. The steel walls of the acceptor container reduced the fragment impact velocities against the TOW acceptors enough to reduce the critical range for a one-percent probability of propagation (IMD, for a detonation) from about 450 ft to about 300 ft.

Figures 8 and 9 are similar calculations for heavy-cased M107 acceptors and the same M107 donors (both SCL No. 37). In this case, the IMD is reduced by more than 50 percent, from 430 ft for open storage of the two loads, to 200 ft for the same loads in ISO containers.

Table 4 compares the "revised" QD's to the "current" QD's for the SCL's containing heavy fragment-producing munitions. The IBD's were calculated using the standard U.S. and NATO hazard criterion of one hazardous fragment impact (i.e., with an impact force of 58 ft-lbs or more) per 600 ft^2 of target presented area, and a one-percent probability of hitting a standing man. For SCL's in ISO containers, only SCL No. 37, with M107 HE-loaded projectiles and an MCE of 6,189 lb, produced an IBD that exceeds the 1,250-ft minimum fragment IBD given by the current standards, or the corresponding 810-ft minimum fragment IBD calculated by FRAGPROP for SCL's in ISO containers. The walls of a donor container were shown to reduce the fragment IBD by about 35 percent for all HD 1.1 loads except SCL No. 37.

IBD's for fragment-producing loads of HD 1.2 munitions were based on the hazard distances for detonations of a single round in each SCL, in accordance with the rule given in Reference 1. The calculations indicated major reductions for the revised IBD's for loads in ISO containers; from distances ranging from 296 to 1,010 ft based on the current standards for the twelve HD 1.2 loads, to 100 ft or less as calculated by FRAGPROP for the same loads in containers. **NOTE:** *FRAGPROP cannot presently calculate IBD's less than 100 ft.*

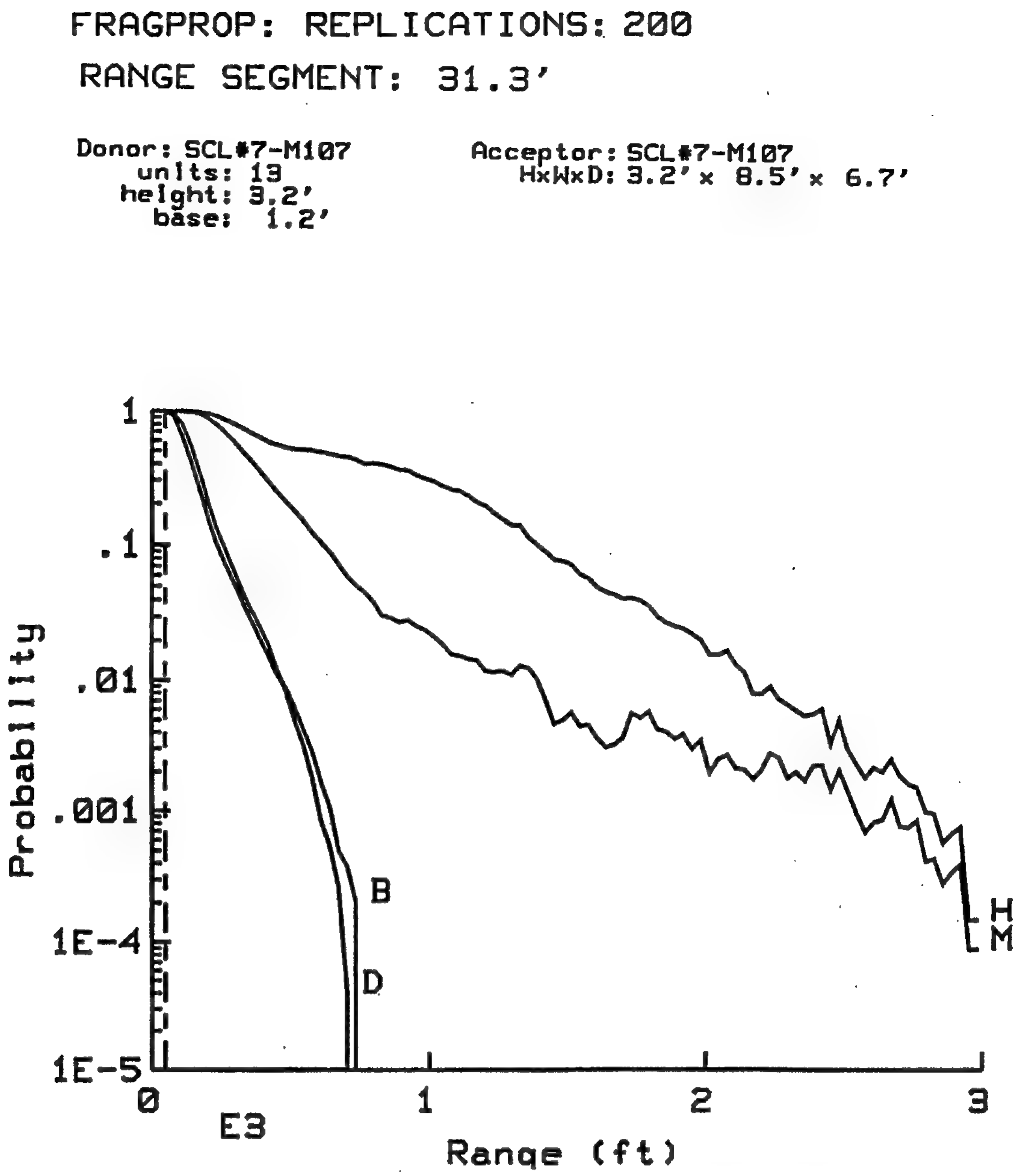


Figure 8. Results of FRAGPROP calculations of the probabilities of different effects from 155-mm M107 (SCL No. 37) donor fragment impacts against similar M107 acceptor loads in the open (i.e., not in containers).

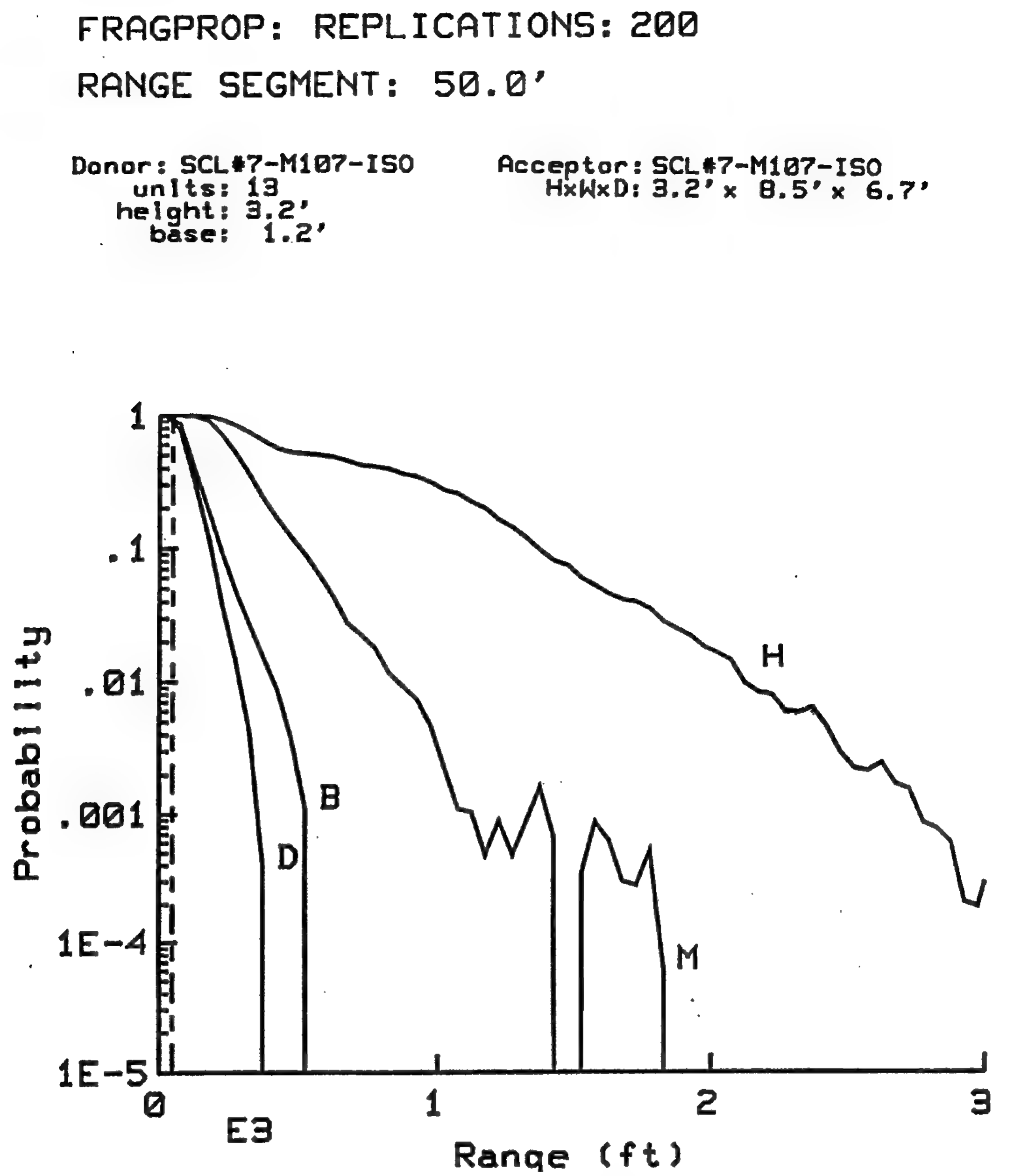


Figure 9. Results of FRAGPROP calculations of the probabilities of different effects from 155-mm M107 (SCL No. 37) donor fragment impacts against similar M107 acceptor loads in containers.

Table 4
Revised QD Values as Calculated by FRAGPROP (FP) for Fragment-Producing SCL's Compared to Values Based on Current U.S. Standards (S)

LOAD NAME	LOAD HD	NEW lbs	NEWQD lbs	MCE lbs	IBD(S) ft	IBD(FP) ft	IMD(S) ft	IMD(FP) ft
ARTILLERY, HE	1.1	6190	6189	6189	1490	1402	202	100*
ARTILLERY, 155mm	1.1	3668	3666	3666	1250	810	170	100*
ARTILLERY, 155mm EX Range	1.1	5438	5436.7	5437	1250	810	193	100*
ARTILLERY, 155mm Smoke	1.1	4978	4976	4976	1250	810	188	100*
INFANTRY, Misc	1.1	2494	824	824	1250	810	103	100*
AVIATION, AH-1	1.1	4090	2898.1	2898	1250	810	300	100*
AVIATION, AH-1	1.1	3372	2507.6	2805	1250	810	300	100*
GENERAL PURPOSE, SAA	1.1	3013	710.96	711	1250	810	98	100*
BRADLEY, M2/M3	1.1	5413	1458	1458	1250	810	180	100*
MORTAR, 4.2 "	1.1	4383	4376	4376	1250	810	200	100*
ARTILLERY, 155mm DPICM	1.1	4497	4326	4326	1250	810	118	100*
AVIATION, AH-64	1.1	13707	5656	5656	1250	810	300	100*
AVIATION, AH-1	1.1	3787	2410.2	2410	1250	810	300	100*
AVIATION, AH-1	1.1	3682	2812.7	2813	1250	810	300	100*
ENGINEER, CEV/165mm	1.1	6437	4829	4829	1250	810	186	100*
ENGINEER, MINES	1.1	4125	4123	4123	1250	810	176	100*
ARTILLERY, RAP	1.1	8717	8715	8715	1250	810	227	100*
MORTAR, 81mm	1.1	1918	1918	1918	1250	810	200	100*
ARMOR, 120mm HEAT	1.2.1	6702	6057	61	1010	100*	200	100*
ARMOR, 120mm APFSDS	1.2.1	6614	5969	60	1007	100*	200	100*
105MM, HE M760	1.2.1	3541	3529	28	1000	100*	200	100*
ARMOR, 120mm PKG A	1.2.1	4989	4988.8	61	978	100*	200	100*
ARMOR, 120mm PKG B	1.2.1	4813	4008.7	61	942	100*	200	100*
105MM, HERA	1.2.1	3890	3855	39	935	100*	200	100*
105MM, HE	1.2.1	2810	2798	47	881	100*	200	100*
105mm Smoke(WP)	1.2.1	2131	2115	40	833	100*	200	100*
105MM, ILLUM	1.2.1	1979	1959	31	820	100*	200	100*
ARTILLERY, ADAMS-L	1.2.1	3958	317	45	492	100*	200	100*
ARTILLERY, ADAMS-S	1.2.1	5088	317.27	45	492	100*	200	100*
MORTAR, 60mm	1.2.2	2626	2596	2596	110	100*	69	100*

Note: Distances for HD 1.1 loads were calculated using the MCE and assuming 155-mm M107 rounds as the fragment source.

Distances for HD 1.2 loads assumed simultaneous detonation of seven 105-mm M1 rounds as the fragment source.

*100 feet is the minimum distance that can be calculated with FRAGPROP. Actual distance may be less.

Airblast Hazards. For airblast, the IMD is that given in the standards for the total MCE of each SCL. Since no general criteria have been developed and demonstrated (as of this date) to provide a justifiable alternative, the K-11 hazard factor in Table 9-5 of DoD 6055.9-STD was used. An exception to this rule is for MCE's of 50 lbs (22 kg) or less of light-cased munitions or bare explosives, where previous tests of detonations in containers (conducted in Germany) show that the combined protection provided by the walls of a donor and an acceptor container will prevent propagation between the containers. Therefore, when the total MCE is less than 50 lbs, the IMD is reduced to a minimum separation distance of 8 ft (2.5m) between containers. Similarly, ILD's can be based on the K-18 value given in the standards, except for MCE's less than 22 lbs (10kg), when it is assumed that the donor container will essentially contain the airblast effects.

IBD's for airblast are based on a criterion of 1.2 psi (8.3 kPa) peak side-on overpressure. A review of the most recent airblast prediction methods (for hemispherical TNT charges on the ground surface at sea level) gives a scaled distance of 15 $m/kg^{1/3}$ for a pressure level of 8.3 kPa, which is only slightly less than the 40 $ft/lb^{1/3}$ scaled distance given in the current standards. PTR values for airblast were based on the 2.3 psi (15.8 kPa) criterion given in DoD 6055.9-STD, which yields a scaled PTR distance of 23 $ft/lb^{1/3}$ ($9m/kg^{1/3}$). Table 5 compares the "revised" QD's to the "current" values for SCL's in ISO containers with only non-fragmenting munitions.

Table 5
Revised IBD and IMD Values for Non-Fragmenting SCL's in ISO Containers, Based on Airblast (AB) Effects, Compared to Distances Based on Current U.S. Standards(S)

LD #	LOAD NAME	LOAD HD	NEW lbs	NEW/QD lbs	MCE lbs	IBD(S) ft	IBD(AB) ft	IMD(S) ft	IMD(AB) ft
3	ENGINEER, BREACHING	1.1	34776	9515.4	9515	1250	848	233	233
4	ENGINEER, MICLIC	1.1	10914	10914	10914	1250	887	244	244
5	ENGINEER. DEMOLITION	1.1	13915	8849	8849	1250	827	228	228
6	ENGINEER, VOLCANO MINE	1.1	5227	5227	5227	1250	694	191	191
10	ARTILLERY, MLRS	1.1	37645	9291	9291	1250	841	231	231
11	INFANTRY,Small Arms	1.4	3881	0	0	100	8	50	50
16	GENERAL PURPOSE, 40mm	1.1	2207	1075	1075	1250	410	113	113
20	TOW 2A	1.1	1136	1135.9	1136	1250	417	115	115
21	DRAGON/AT-4	1.1	417	417	417	670	402	200	200
24	ARTILLERY, ATACMS	1.1	7400	1640	1640	1250	472	130	130
29	ENGINEER, MOBILITY	1.1	9307	7811	7811	1250	794	218	218
30	ENGINEER, DEMO	1.1	16240	11228	11228	1250	896	246	246
34	ARTILLERY, RAAMS-S	1.1	6743	6742	6742	1250	756	208	208
35	ARTILLERY, RAAM-L	1.1	6743	6742	6742	1250	756	208	208
38	ARTILLERY, ILLUM	1.3	4482	4479	0	132	0	82	82
39	ARTILLERY, COPPERHEAD	1.1	2194	2192	2192	1250	520	143	143
40	AIR DEFENSE, STINGER	1.1	1142	94	94	1250	182	50	50
41	MORTAR, 120mm	1.1	3040	3040	3040	1250	579	159	159
49	KIOWA WARRIOR OH-58D	1.1	1568	817	817	1250	374	103	103

4 Phase 1b: Concepts for QD Reduction

Protection Concepts

The second principal objective of the Container QD Study was to evaluate the effectiveness of different concepts for mitigating the hazardous effects of a donor container detonation. Table 6 lists a number of mitigation methods that were initially considered. Three of these were investigated in the analysis: (a) to reduce the donor MCE by buffering subdivisions of the HD 1.1 components of the donor load with HD 1.4 (and possibly 1.3) components; (b) to protect acceptor loads from the fragments of a donor detonation by installing shielding panels; and (c) to protect acceptor loads by using barricades. These concepts are discussed in detail in the following sections.

Buffering Donor Munitions

The results of the Literature Survey indicated that a concentration of HD 1.1 munitions in certain loads could be re-arranged so as to place HD 1.3 or 1.4 items between subdivisions of the HD 1.1 items. The load plan for SCL No. 7, for example, is shown in Figure A2. The three rows of HD 1.1 155-mm M483 projectiles (DODIC D563) in the center of the load could be buffered separated by placing the pallets of HD 1.3 propelling charges (DODIC D533 and D541) between them, Although a detonation of any one subdivision of the HD 1.1 projectiles would also detonate the adjacent propellant, the prop charges should absorb the HD 1.1 fragments and prevent the buffered HD 1.1 subdivisions from detonating by fragment impacts. If so, the MCE of the load would be significantly reduced. Unfortunately, the Literature Survey did not produce reliable data to show whether or not heavy-cased HD 1.1 items could or could not be sympathetically detonated by the blast pressure alone from adjacent propellant detonation. However, other loads containing HD 1.4 components, rather than HD 1.3, would almost certainly be candidates for donor buffering.

Table 6
General Attributes of Potential Protection Methods for ISO Containers of Ammunition

- **BALLISTIC BLANKETS (Kevlar, nylon blankets, quilts, etc.)**
  - Re-usable
  - Expensive
  - Unproven effectiveness for containers
  - Ineffective for high-speed fragments
  - Eliminated from consideration in this study

- **SHIELDING OF CONTAINERS**
  - Inexpensive
  - No labor requirement
  - Re-usable
  - Limited effectiveness

- **BUFFERING (Shielding of HD 1.1 with other HD components)**
  - Re-arrangement of load plans
  - No cost, no labor
  - High potential effectiveness
  - Limited applications

- **SHIELDING OF LOAD COMPONENTS**
  - Minimum labor requirement
  - Re-usable or disposable
  - High potential effectiveness
  - Limited applications

- **SAND-FILLED BARRICADES**
  - Highly effective
  - Construction labor required
  - Limited re-usability
  - Some separation distance still required
  - Proven performance (for most types)

Shielding of Acceptor Containers

The Literature Survey revealed several studies in which relatively thin layers of various materials were shown to be effective in reducing the velocity of penetrating fragments. The THOR equations were used to calculate the residual velocity, shown in Figure 10, of a standard fragment when penetrating (a) the steel wall of an ISO container, (b) a container wall backed by a 3/4-inch panel of plywood, and (c) a container wall backed by a 1/8-inch and 1/4-inch steel plate. Assuming that a fragment impact velocity of 450 ft/sec is required to initiate an acceptor munition, the additions of the plywood and 1/8-inch steel shields reduced the residual velocity of a penetrating fragment at the critical range by 15 and 100 percent, respectively. These velocity reductions would allow the safe separation distance (calculated by FRAGPROP) between a donor and an acceptor container to be reduced from 530 ft (162 m) to 485 ft (148 m) and 350 ft (107 m), or 8 and 34 percent, respectively.

Figure 1 shows the interior dimensions and the weight data for a standard, 20-ft ISO container. By installing such shielding panels against the interior sidewalls above the level of a flat-rack platform, an SCL could be inserted and removed with no interference. One layer of 3/4-inch plywood along each sidewall would increase the tare (empty) weight of a container by about 600 lb, or about 14 percent. Other materials may be even more effective as relatively light-weight fragment shields. If a greater shielding thickness is required, only the presented area of the HD 1.1 components on each side of a load might be shielded.

Barricades

The most obvious method to reduce IMD's is to place barricades between containers to prevent a propagation from one to another. An ARL test several years ago (Reference 9) showed that a sand-grid barricade was highly effective in preventing propagation between adjacent truckloads of artillery ammunition. ARMCO barricades, which are 5.25 ft-thick steel bins filled with sand, have been accepted by DDESB for NEW's up to 5,000 lb (Reference 10).

A recent innovation in barricade design is the Hesco-Bastion barricade, which consists of canvas boxes, supported by collapsible wire frames and filled with soil or sand. The "Concertainer" barricade is a Hesco-Bastion type in which a line of boxes is connected accordion-style for compact shipping and storage. The concertainer barricade can be rapidly set up by a few troops using a dump-loader (see Figure 11).

The U.S. Second Infantry Division began using Concertainer barricades in 1997 to protect ammunition-filled containers at their camps in Korea, as shown in Figure 2. In the summer of 1998, a full-scale test of the Concertainer barricade was conducted in Denmark, involving the detonation of a 1,000-kg

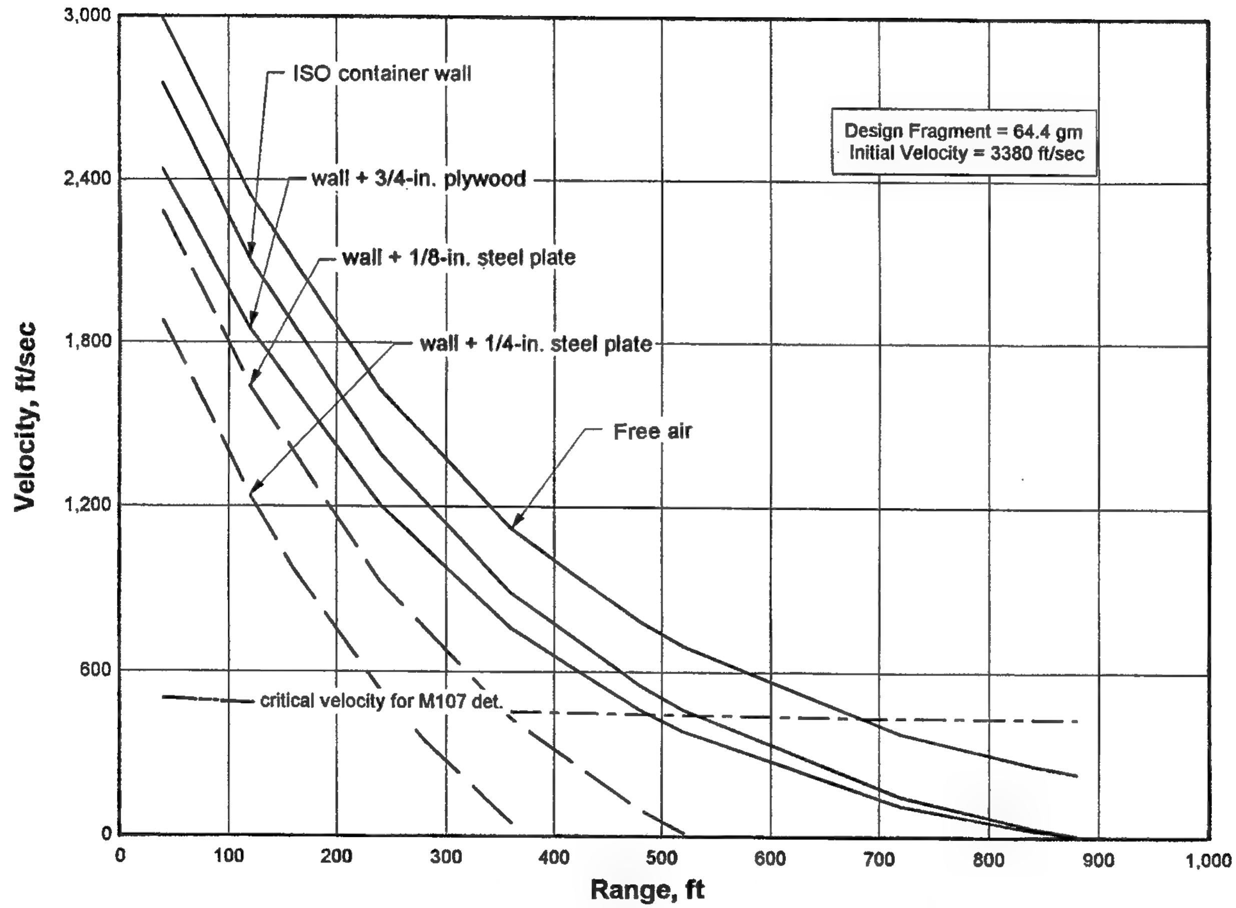
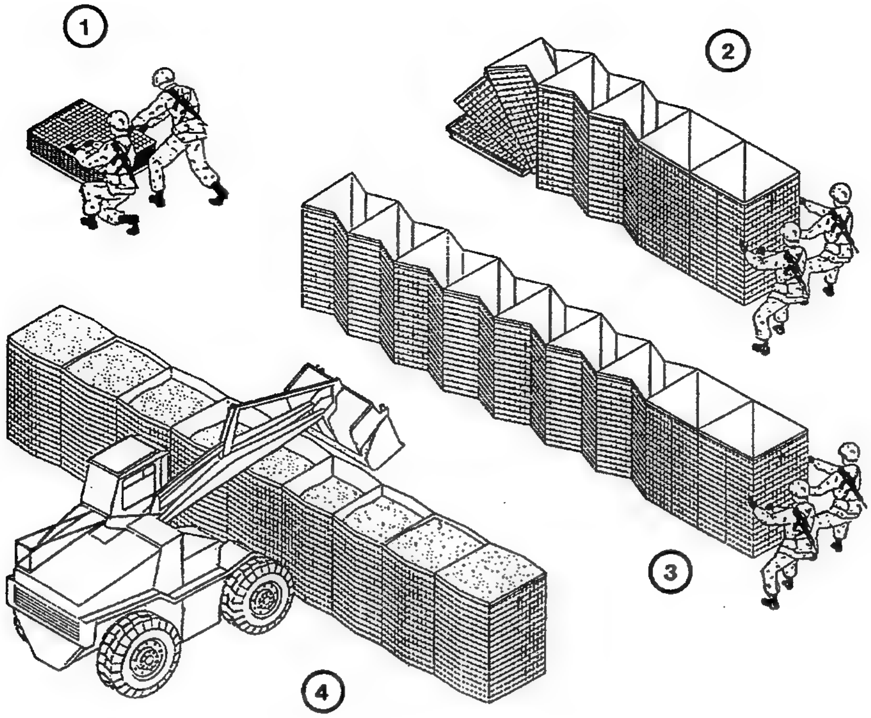


Figure 10. Calculations of residual velocity of standard design fragments from 155-mm M107 HE-loaded projectiles, after passing through free air, acceptor ISO container wall panels, and wall panels backed by plywood or steel plate, as a function of range from detonation



a. Construction

b. Completed wall

Figure 11. Construction of a sand-filled Hesco-Bastion "Concertainer" wall,

NEQ in a donor container (Reference 11). Figure 12 shows the test layout. The adjacent acceptor container survived with relatively little damage.

Protection Provided by Containers

The Airblast Threat

If a donor container contains no HD 1.1 material, then there is no risk of a mass detonation of the donor container contents. Consequently, there is no significant airblast threat. For any donor containing HD 1.1, there is a risk of a mass detonation and a resulting propagation to adjacent containers by airblast effects (due to crushing of the acceptor munitions). If the airblast impacts an acceptor container with no HD 1.1 material, there is, by definition, no risk of a mass detonation of the acceptor. For such cases, it is proposed that the airblast-based IMD for containerized HD 1.2, 1.3 and 1.4 ammunition be set to a default minimum of 8 feet (2.5 m).

For acceptors containing HD 1.1 material, it is assumed that an airblast loading above some critical level of intensity could crush munitions in the acceptor container (or knock them against each other with sufficient force) to the point that an acceptor munition reacts, and initiates the entire acceptor container in a mass detonation. Therefore, the IMD between HD 1.1 containers must be sufficient to ensure that the airblast loading cannot cause such a reaction.

For IBD and PTR, the airblast damage threshold (1.2 psi or 8.3 kPa for IBD) is so low that the airblast threat out-ranges the fragment threat for MCE's greater than about 30,000 lbs (13,700 kg) in open storage. For IMD, however, the airblast threshold for propagation is much higher, so it is always out-ranged by the fragment threat from heavy-cased munitions. The airblast threat for IMD is therefore limited to those HD 1.1 donor containers that contain only light-cased or bare charge munitions (such as demolition charges, mines, most rockets and missiles, etc.).

The Literature Survey revealed a number of studies that provided information on the sensitivity of various munitions to crushing loads produced by airblast effects. This information could not be adapted to this study, however, because the protection provided by the container against the direct airblast loading is an unknown factor. It is known, however, that ammunition must survive "drop tests" from a standard drop height of 40 feet, without causing a detonation (although an ISO container may be destroyed in the process). It seems reasonable that a munitions-loaded ISO container should be able to survive the same impact load produced by airblast from a nearby container detonation. Therefore the proposed IMD from an airblast threat is that which would produce loading conditions on an acceptor container equivalent to those produced in a 40-ft drop test.

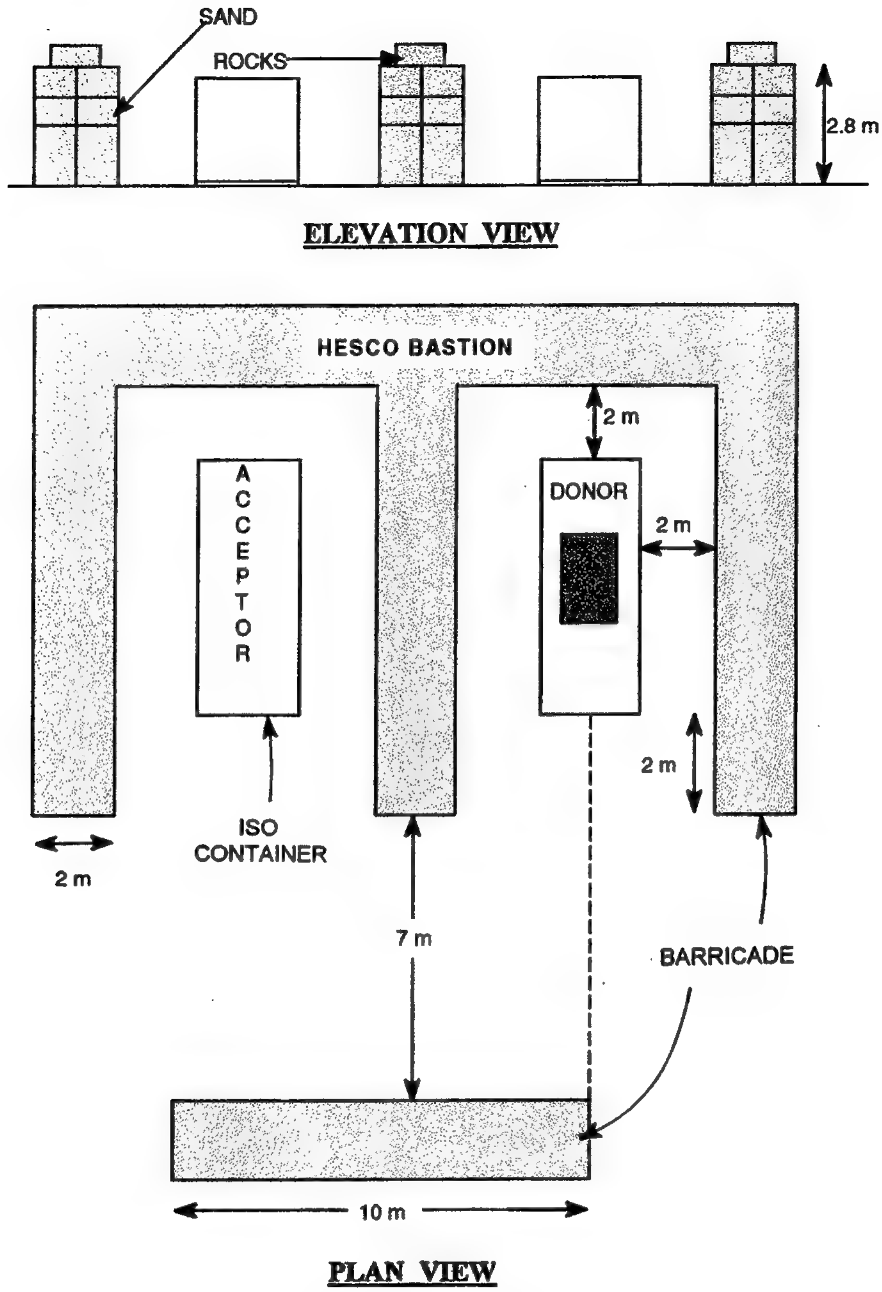


Figure 12. Layout of Hesco-Bastion barricades and ISO containers for the 1998 Danish experiment. The donor contained 1,000 kg NEQ of 155-mm, TNT-loaded artillery projectiles, and the acceptor contained packages of plastic explosive.

From Appendix A, it can be seen that the heaviest SCL loads are those containing uncased or light-cased HD 1.1 munitions, such as SCL No. 3 (demolition explosives) or No. 10 (MLRS rockets). These have loaded container gross weights of up to 40,000 lbs (18,000 kg).

If a container of this weight is dropped from a height (h) of 40 ft, the dynamic stress on the container produced by the impact with the ground surface can be approximated by equation:

$$\sigma = \rho_s c_s V / (1 + \rho_s c_s / \rho_c c_c)$$

where

σ = the peak dynamic stress at the container/ground interface at the instant of impact

$\rho_s c_s$ = the acoustic impedance (density times acoustic velocity) of the ground material

$\rho_c c_c$ = the acoustic impedance of the loaded container

and

V = the container impact velocity against the ground surface.

The impact velocity will be $V = \sqrt{2gh}$, which will be about 50 ft/sec for a 40-ft drop. The acoustic impedance of a typical sandy soil is about 30 psi-ft/sec. For the loaded container, the density would be 40,000 lbs/ 1,280-ft^3, or 31 lbs/ft^3. If we use a 20,000 ft/sec acoustic velocity of steel to represent the loaded container, then the container impedance is about 135 psi-ft/sec. Substituting these values into the equation gives a stress of 1,200 psi on the base of the container from the impact of a 40-ft drop.

We assume, then, that an ammunition-filled container can withstand a stress of 1,200 psi from a ground impact after a 40-ft drop without a reaction occurring. For convenience, we can assume that the impact of an airblast load which produces an equivalent stress (i.e., equal to a reflected pressure of 1,200 psi against the sidewall of an acceptor container) should produce no more damage than the impact against the ground surface from a 40-ft drop.

Airblast prediction guides show that an airblast peak incident pressure of 200 psi, impacting a container wall at a 0-degree angle of incidence, will have a reflection coefficient of 6.0, which yields a 1,200-psi peak reflected pressure. For a surface-burst explosion, a 200-psi (1.38-mPa) incident pressure should occur at a scaled distance of about 1.0 m/kg$^{1/3}$, or 3.0 ft/lb$^{1/3}$.

An experiment was planned for Phase 2 of the program specifically to validate a proposed scaled distance of 1.0 m/kg$^{1/3}$ as the IMD for the airblast threat. The test involved an acceptor container of "worst case" munitions with regard to sensitivity to shock and crushing effects. Since the applied loading was airblast

only, a donor container was not required. The donor was a stack of explosive with an NEW of 2,200 lbs, located 26 ft (9.7 m) away from an acceptor container carrying a variety of HD 1.1 and HD 1.2 munitions. This provided a conservative standoff distance that was 30 percent less than the 1.0 $m/kg^{1/3}$ of the proposed IMD. Details of this experiment (Test B1) are given in the following chapter.

The Fragment Threat

A fragment must impact an acceptor munition with a certain minimum amount of energy in order to cause a reaction (high-order detonation, low-order detonation, or burn) in the acceptor. The FRAGPROP model defines the critical energy thresholds for specific acceptors.

By definition, HD 1.2, 1.3, and 1.4 acceptor munitions will not mass detonate if no HD 1.1 material is present, even though one or more items in the acceptor stack may individually detonate from donor fragment impacts. It is therefore assumed that the fragment-based IMD between any type of donor and HD 1.2, 1.3, or 1.4 acceptors is negligible. For such cases, it is proposed that the *fragment-based* IMD for containerized ammunition be set to a default minimum of 8 feet, or 2.5 m.

A revised IMD between any fragment-producing donor and an HD 1.1 acceptor was calculated for containerized ammunition using the FRAGPROP code in the analysis described earlier. This revised IMD was based, in part, on FRAGPROP-calculated reductions in the fragment impact energy after a (standard) fragment penetrates the wall of the acceptor container (for HD 1.1 donors), or the walls of both the donor and acceptor containers (for HD 1.2 donors).

The associated reductions in IMD were significant. However, two serious problems remain. First, FRAGPROP does not calculate IMD's less than 100 feet (30 m). Second, the effectiveness of container walls in reducing fragment velocities has not been demonstrated. To address these needs, a series of tests (Test Series A) was planned for Phase 2 to assess the effect of container walls on fragment impact velocity. Rounds of fragment-threat munitions were detonated above a testbed of sand containing plastic witness sheets at 4-inch (10-cm) intervals of depth. By plotting the number of fragment holes as a function of the depth of the sheet, a basis could be established for defining the fragment penetration capability. By correlating the collector material density, and the fragment penetration depth to the initial fragment impact velocity, a plot can be made of residual fragment energy as a function of depth along the penetration path for a fragment of a given mass and shape.

The degree of protection provided by a steel container wall can be defined by the reduction in fragment energy (or velocity) after the wall is penetrated. To determine this reduction, a second, identical test was conducted with a steel plate, having the same strength and thickness as a container wall, suspended over the testbed. By comparing the maximum fragment penetration depth from this test

with that of the previous test, a new impact velocity against the testbed can be calculated (not exactly, but as a close approximation). This will then indicate the amount of velocity (or impact energy) lost from the wall penetration.

Test Data Requirements

The analysis phase of the program identified two general areas for which test data is needed for validating current QD's, or justifying reduced QD's for ammunition stored in ISO containers. Both relate to IMD's; i.e., the safe separation distances between containers that are needed to prevent propagation. The following sections describe the nature of these needs and the types of tests recommended to address them.

Validation of Reduced IMD's

Intermagazine distance (IMD's) are defined by the most severe of two types of hazards from a donor explosion that may induce a detonation of munitions in an acceptor stock - - fragments (or other debris) or airblast. ARL and other organizations have performed extensive studies of propagation by fragment impacts (see Reference 8, for example). While additional test data would be beneficial, such tests are beyond the scope of this study. Test data are needed, however, to verify the extent to which ISO container walls can reduce fragment ranges and impact velocities against acceptor munitions, and thereby reduce QD's. This effect is addressed under "Shielding", in the next section.

For non-fragment-producing munitions, the revised QD's given in Table 5 are based on donor airblast effects. Test data is needed to verify that IMD's as small as 2.0 $ft/lb^{1/3}$ (0.8 $m/kg^{1/3}$) will, in fact, be sufficient to prevent propagation between ammunition loads in ISO containers.

Validation of Protection Concepts

As discussed earlier, several concepts were identified that could potentially reduce QD's by mitigation of fragment and airblast effects. Due to funding limitations, however, only two of these concepts—shielding and barricades—could be investigated experimentally in Phase 2 of the study.

Shielding. The most important shielding effect of interest is that provided by ISO container wall panels against outgoing and incoming fragments. The fragment penetration (into a sandbed) experiments described earlier included tests with and without steel panels representative of container walls.

Barricades. The results of previous, related test programs strongly indicate that the standard 1.2 m-thickness of a sand or earth-filled barricade, such as the Hesco-Bastion "Concertainer" type, will prevent propagation between ammunition-filled containers. Since the largest NEW tested against such a barricade to date was the 1,000-kg Danish test in 1999 (Reference 11), there is a need to clearly validate the performance of such a barricade for a donor detonation more representative of the larger NEW's planned for U.S. and U.K. SCL's.

A new concept for a sand-filled barricade is the "Blast-Tamer", which employs sidewalls of rigid, fire-resistant, polyurethane foam. This type of barricade construction may offer some significant advantages over the Hesco-Bastion and other existing types, in terms of ease and speed of construction, re-usability, and other factors. However, it has not been "performance-tested" as a propagation barrier.

Although previous research has shown that sand-filled barricades are very effective in stopping fragments, the airblast load against a vertical barricade may be sufficient to drive the barricade mass against an acceptor container with tremendous force—enough to smash the container and seriously damage the munitions inside. This is, in fact, the reason that concrete wall panels cannot be used for such purposes—the impact of the concrete fragments may, in some cases, cause the acceptors to detonate. Sand or earth, on the other hand, tends to flow around small, dense impact targets such as munition rounds, which greatly reduces the impact force.

Recent hydrocode calculations of barricade performance by the U.S. Army Research Laboratory (ARL) (Reference 12) indicated that a barricade with sloping, rather than vertical, faces would not only stop fragments, but would deflect much of the airblast load in an upward direction. The barricade performance test planned for Phase 2 was therefore designed to evaluate a "slope-sided," sand-filled barricade, to determine if such a design would significantly reduce damage to munitions in an acceptor container.

While sand-filled barricades appear to be very effective barriers to fragments, all types tested to date have been at least one meter thick. The sandbed tests described earlier were expected to provide definitive information on the depths to which fragments from heavy-cased donor munitions penetrate into sand. If these depths are significantly less than one meter, it is possible that thinner barricades (say, 50 cm) would perform satisfactorily. A test requirement was therefore identified to determine how thin a sand-filled barricade can be to remain an effective propagation barrier.

A barricade experiment was designed for Phase 2 to address these issues. The test involved a donor container of heavy fragment-producing, M107 projectiles, with an NEW of 6,200 lbs (2,820 kg), and acceptor containers on each side, also containing M107 projectiles. One acceptor was protected by a "slope-sided", sand-filled Blast Tamer barricade, and the other by a 0.5-m thick, "thin", sand-filled Blast Tamer barricade with vertical sidewalls.

Spacings between the donor container and the barricades, and between the acceptor containers and the barricades, were 8 ft (2.5 m). This was assumed to be the minimum practical separation distance in a temporary storage situation; i.e., to still allow room for safety inspections and fire-fighting operations.

Summary of Findings From Analysis

Effect of Containers on QD's

For HD 1.1 Ammunition. The analysis indicated that the containers themselves have no significant effect on IBD or PTR for HD 1.1 materials, compared to open storage without containers. Containers do have some beneficial effect with regard to safe separation distances (IMD). The FRAGPROP calculations indicated that the steel walls of acceptor containers will reduce the impact velocities of incoming fragments against munitions inside the containers. This equates to a small reduction in the IMD required for a one-percent (or less) probability that an acceptor round will detonate from a donor fragment impact. The analysis indicated that the IMD from a light-cased donor, which is based on the airblast threat alone, is significantly reduced. Although an acceptor container may be totally destroyed by airblast, this does not happen instantaneously. The acceptor container structure reflects and/or absorbs much of the initial, high-pressure "spike" of the airblast shock front, which greatly reduces the shock load on the munitions inside.

For HD 1.2 Ammunition. The analysis showed that containers may provide a major reduction in IBD and PTR for HD 1.2 munitions. Since HD 1.2 material does not mass detonate, this means that an accidental explosion in an HD 1.2 *acceptor* container will be limited to only a few rounds, at most—those that (a) are on the side of the load facing the donor, and (b) receive donor fragment impacts sufficient to cause detonations. The container walls inhibit the outgoing fragments from an HD 1.2 donor by slowing those striking the walls directly, and by deflecting those striking the wall at sharp oblique angles.

The IBD and PTR reductions indicated in the "revised" QD's for HD 1.2 donor containers may not occur, if the initial detonation is a cook-off from a fire inside the container. The fire may continue to burn and cook off additional rounds after the container walls are blown away by the first one or several detonations. Fragments from these rounds therefore would not be retarded by the container walls.

IMD's for donor HD 1.2 loads in containers should be reduced significantly, since the walls of both the donor and acceptor containers will reduce fragment impact velocities against acceptor munitions. Again, an exception may be for a fire in a donor container, in which case only the acceptor container walls would retard fragments.

For HD 1.3 Ammunition. It was assumed in the analysis that HD 1.3 items, when not mixed with HD 1.1, (a) do not contribute to IBD or PTR distances, and (b) cannot be initiated by fragment or airblast threats from other donors. Consequently, the IMD for HD 1.3 material is limited to that necessary to prevent initiation by spread of a fire. Since the containers shield their contents against firebrands, the recommended minimum IMD is 8 ft, for inspection and fire control access.

Calculations of QD's

The reductions in QD's indicated by comparing the "revised" QD's with "current" QD's in Tables 4 and 5 stem from two sources; the effect of the containers themselves (compared to open storage), and the use of available prediction methods to calculate fragment and airblast hazards for the "revised" QD's. While FRAGPROP is an extremely valuable tool for predicting the fragment hazards, the program has some limitations that should be recognized.

First, the current program only has two sources of donor fragments that can be used in any calculation: 155-mm M107 projectiles, and 105-mm HE projectiles—and two types of acceptors: M107 projectiles representing heavy-cased munitions, and TOW-2B warheads representing light-cased munitions. While these donor and acceptor models are satisfactory representations of many other munition types, they may not be suitable for all types.

Secondly, the fragment data on which FRAGPROP predictions are based does not allow reliable predictions of fragment effects at distances less than 100 ft (30m). Consequently, the minimum "revised" QD's calculated for fragment-producing munitions are limited to 100 ft. In reality, the fragment-based QD's for HD 1.2 munitions may be much less than this value.

Reduction of QD's by Hazard Mitigation Techniques

Shielding and Buffering. The revised QD's in Table 4 include the shielding effect of container walls (for reducing fragment velocities) as a reduction in IMD for HD 1.1 munitions, and reduction of IBD, PTR, and IMD for HD 1.2 munitions. FRAGPROP calculations indicated that these distances would not be significantly reduced by the addition of 1/4-in. plywood panels to the inside walls of the containers. The addition of 1/8-in. (3.2-mm) steel plates could reduce the IBD and PTR distances by as much as 40 percent, and IMD by about 25 percent. The benefit of these reductions may be offset, however, by the disadvantage of the additional weight added to the containers. Consequently, additional shielding was not addressed further.

Buffering HD 1.1 items with HD 1.4 material or other inert items has been shown to be effective in reducing MCE's in U.S. Air Force experiments (Reference 13). Both the practicality and the benefit of buffering container loads are questionable, however, due to the limited amount of suitable buffer items in

most mixed loads, and the fact that reducing the MCE by, say, a factor of three would only reduce airblast-based QD's by 40 percent (by cube root scaling of blast effects) and fragment-based QD's only by a very small amount. Because of these limitations, buffering also was not considered further.

Barricades. Experiments have shown that propagation between container-sized ammo loads can be prevented by sand-filled barricades. The barricades have little or no effect on IBD or PTR distances, but IMD's can be reduced to tens of meters or less. Unlike solid barricades, such as concrete wall panels, sand-filled (or soil-filled) barricades do not pose a risk of initiating acceptor munitions by their impact force because of the sand's tendency to flow around an impacted solid object.

Sand-filled barricades tested to date, such as the Hesco-Bastion type, have been a meter or more thick. The practicality of their use in temporary storage situations would be greatly enhanced if they could be constructed of thinner dimensions (less material and time requirements for construction), if they were re-usable from site to site, and if the spacings between the barricades and the containers could be reduced to the recommended 8 ft (2.4 m) needed for inspection and fire-fighting access.

5 Phase 2: Experimental Program

Purpose

The experimental program conducted as Phase 2 of the Container QD Study was designed to address the most important requirements for test data that were identified in the analysis of Phase 1. These needs apply specifically to ammunition in ISO containers, although much of the information may also be applicable to other temporary storage situations.

The three principal requirements that were identified all related to safe separation distances (IMD's) between containers. The first two are concerned with the protection provided by containers against propagation from donor containers of heavy-cased (robust) munitions, and the airblast threat from containers of light-cased munitions. The third requirement was for test data to better define the potential benefits of sand-filled barricades for further reducing safe separation distances between containers.

Objectives

Three separate experiments were performed to address these test requirements. The specific objectives were as follows:

Test Series A: The Fragment Threat

a. Define the extent to which the sand in sand-filled barricades retards the velocity of heavy-cased HD 1.1 and HD 1.2 munition fragments.

b. Validate the shielding effect of container wall panels on fragment velocities.

Test Series B: The Airblast Threat

Verify that a separation distance of 2.0 ft/lb$^{1/3}$ (0.8 m/kg$^{1/3}$) will prevent propagation between a donor container of light-cased munitions and an acceptor container of mixed munitions.

Test C: Barricade Performance

a. Validate that a sandfilled barricade 3.0 to 3.5 ft (~1.0.m) thick will prevent propagation between munition containers at a container-to-barricade spacing of 8 ft (2.5 m).

b. Verify the performance of a sand-filled barricade of the minimum thickness required to prevent propagation (by reducing fragment velocities below the critical level), as indicated by the results of the Test A Series and FRAGPROP calculations, for a container-to-barricade spacing of 8 ft (2.5 m).

c. Evaluate the time and effort required to construct Blast-Tamer barricades.

Test Designs

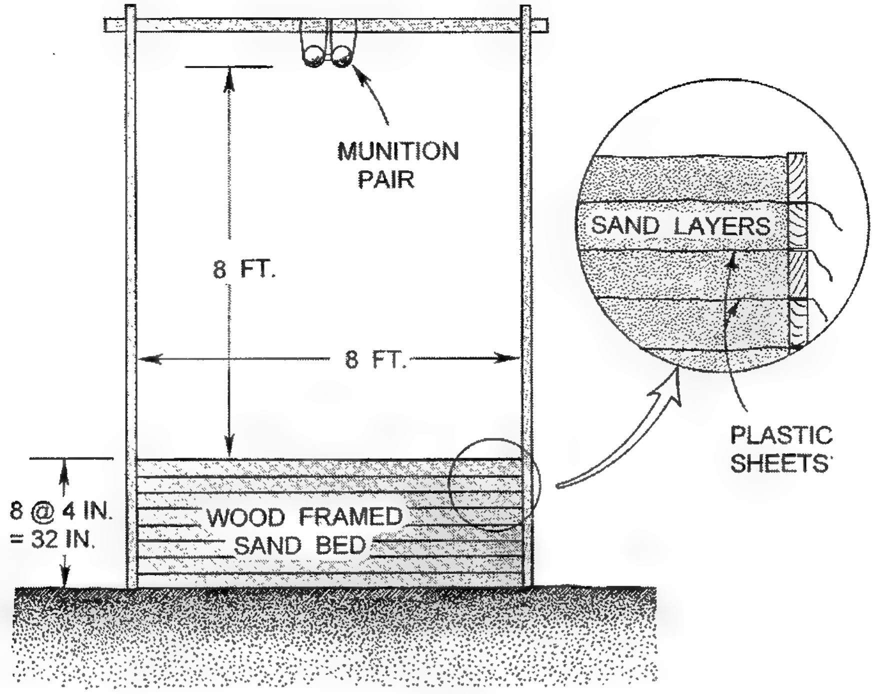
Test Series A: The Fragment Threat

Test A1:

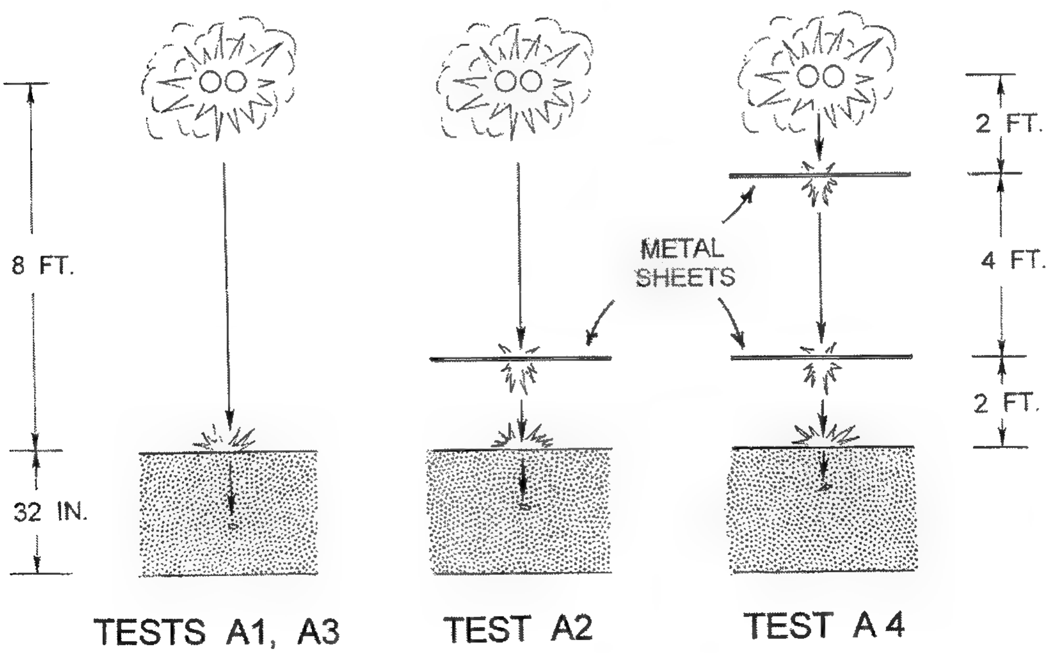
Donor – A pair of M107 projectiles was suspended horizontally approximately 8 ft above a prepared sand bed, as shown in Figure 13. The projectiles were separated 0.75 in. (2.0 cm) inches horizontally, corresponding to the separations between munitions on a standard pallet. The munitions were detonated simultaneously from a common detonating cord that was initiated at the other end by a blasting cap.

Acceptor – The acceptor was an 8-ft (2.5-m) square, 30-in. (76-cm) deep bed of sand centered below the munition pair. The sand bed was laid with witness sheets of heavy plastic at 4-in. (10-cm) depth intervals below the testbed surface. Each layer was numbered to identify its depth.

Measurements – After each test, the plastic witness sheets were removed and the location and total number of fragment penetration holes were recorded. Plots of the number of penetration holes in the plastic witness sheets, as a function of the sheet depth, were made to define the maximum penetration depths of the fragments.



a. Sandbed test set-up for fragment penetration measurements.



b. Simulation of container wall penetrations.

Figure 13. Test geometries to determine effect of container walls (represented by metal sheets) on fragment penetration into sand. Test A2 simulates an acceptor container wall, and Test A4 a donor (top) and acceptor (lower) container wall.

Test A2:

Donor – Same as Test A1.

Acceptor – Same as Test A1, but with a 1.5-mm-thick panel of sheet metal suspended horizontally 2 feet (61 cm) above the sandbed (see Figure 13).

Measurements – Same as Test A1.

Test A3:

Donor – Same as Test A1, but using 105-mm HE projectiles instead of M107's.

Acceptor – Same as Test A1.

Measurements – Same as Test A1.

Test A4:

Donor – Same as Test A3.

Acceptor – Same as Test A2, but with the addition of a panel of sheet metal suspended horizontally 2 feet (61 cm) below the munitions (see Figure 13).

Measurements – Same as Test A1.

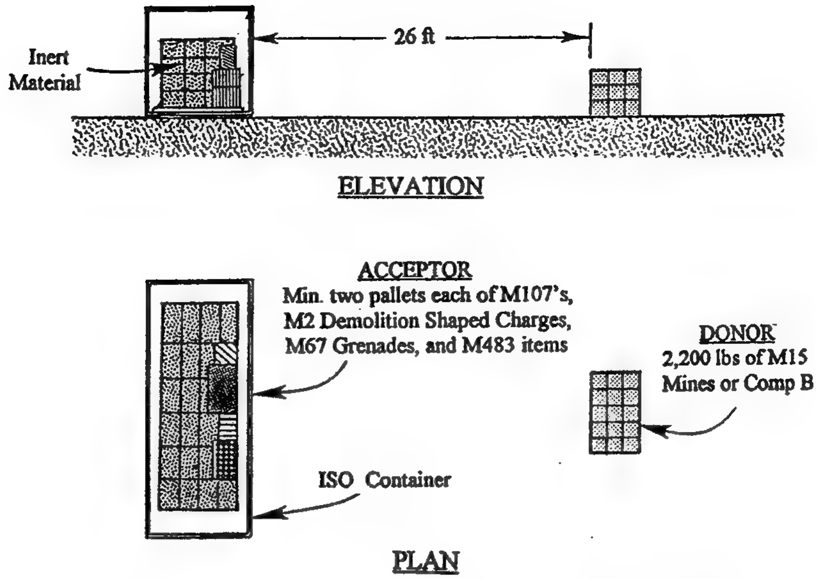
Test Series B: The Airblast Threat

Test B1:

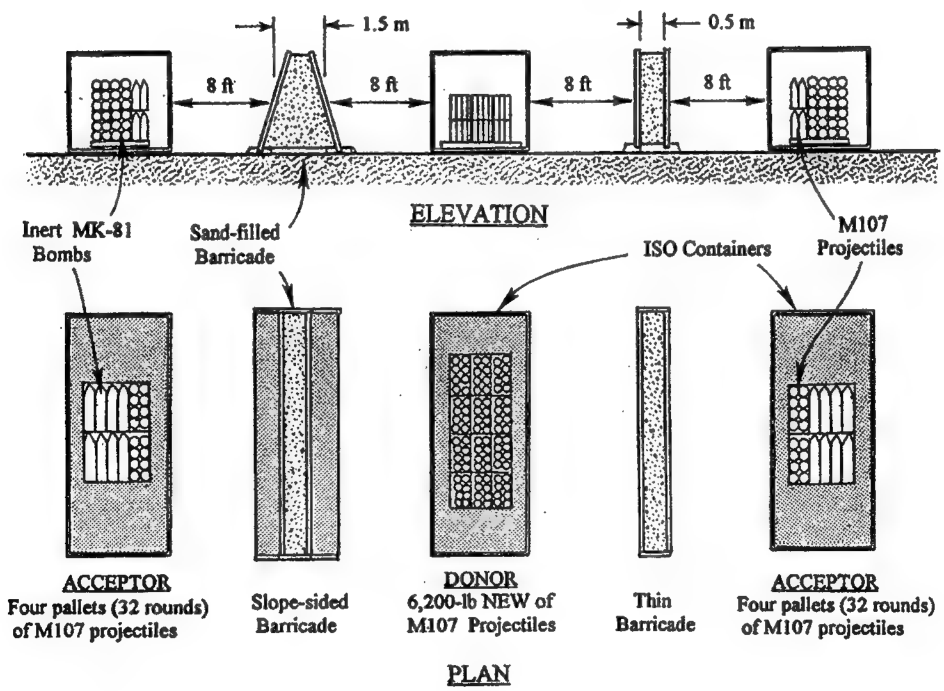
Donor – An open stack of Comp B explosive with an NEW of 2,200 lbs (NEQ of 1,000 kg). See Figure 14a.

Acceptor – An ISO container located 26 ft (8 m) from the donor, containing two pallets each of 155-mm M107 projectiles, M2 demolition shaped charges, M67 hand grenades, and M483 submunitions, all in their normal storage packaging and stacked on the side of the container facing the donor.

Measurements – Steel witness plates were placed below the acceptor pallets to record the level of acceptor reactions. Video and high-speed cameras were used to photograph the response of the acceptor container and munitions. A post-test survey was made to record the condition and dispersion of the acceptor container and its contents.



a. **Tests B1 and B2. M2 demolition shaped charges in Test B1 were replaced with 105-mm HE projectiles in Test B2.**



b. **Test C, with Blast-Tamer barricades.**

Figure 14. Experiment designs for Test B Series and Test C.

Test B2:

Donor – Same as Test B1.

Acceptor – Same as Test B1, but with the M2 demolition shaped charges replaced by 105-mm HE projectiles.

Measurements – Same as Test B1.

Test Series C: Barricade Performance

Donor – 6,200-lb NEW (400 rounds) of 155-mm, Comp B-loaded M107 projectiles in a donor ISO container (see Figure 14b).

Acceptors – On each side of the donor, an ISO container containing six pallets (48 rounds) of 155-mm M107 projectiles, stacked two pallets high on the side of the container nearest the donor. The remainder of each acceptor load consisted of MK-81 bombs with inert fillers, to provide a reaction mass simulating the size and weight of palletized M107 projectiles.

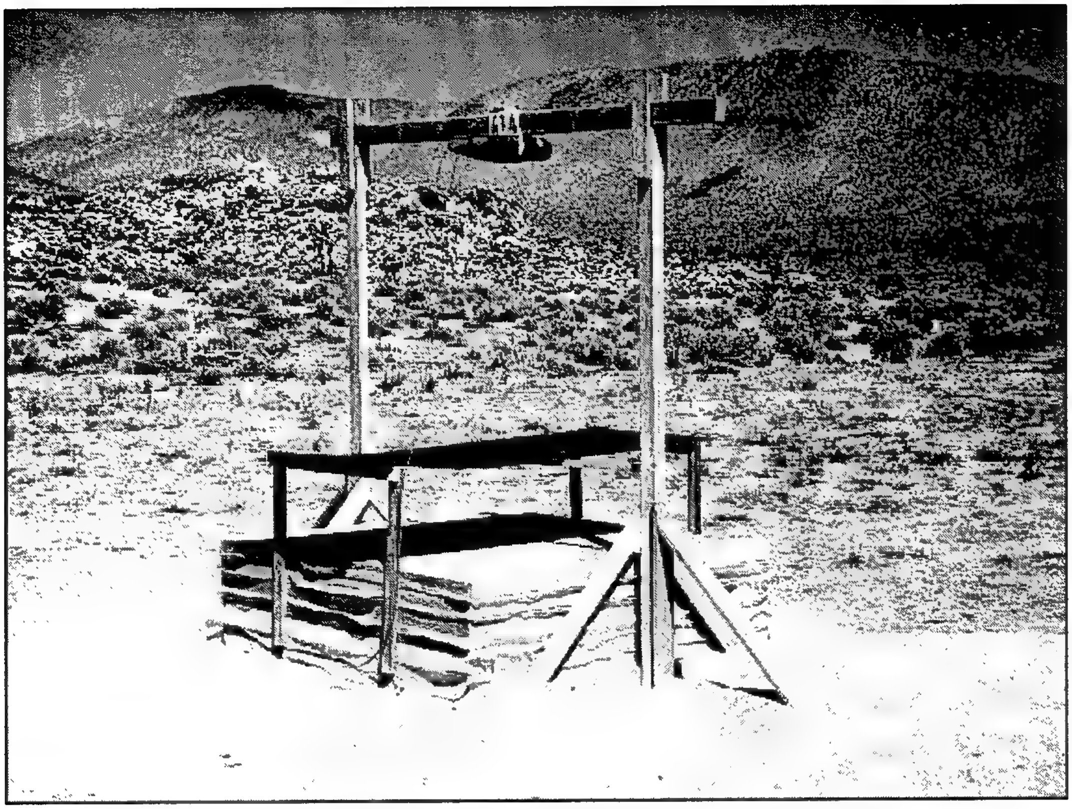
Barricades – At 8 ft (2.5 m) to one side of the donor, an 8 ft-high, sand-filled Blast Tamer barricade with a mid-height thickness of 5.0 ft (1.5 m), with each side of the barricade sloping inward at an angle of 30 degrees from the vertical. At 8 ft to the other side of the donor, an 8 ft-high, sand-filled Blast-Tamer barricade 1.5 ft (46 cm) thick, with vertical sides.

Measurements – Video and high-speed cameras were used to record the detonation, the behavior of the barricades, and the response of the acceptor containers. A post-test survey was made to record the condition and dispersion of the acceptor containers and their contents.

TEST RESULTS

Test Series A

Figure 15a is a photograph of a typical test set-up for the Test A series, in which 155-mm M107 and the 105-mm HE projectiles were detonated above the sand beds. Figure 15b is representative of the results of Tests A2 and A4, in which a metal panel of the same material and thickness as ISO container walls was suspended over the test bed, for Test A2, and both below the munitions and over the test bed, for Test A4.



a. Test set-up with simulated container wall suspended two feet above

b. Testbed surface after detonation

Figure 15. Test A2, with a pair of M107 projectiles

As predicted, the fragment jet formed by the interaction of the fragment sprays from the two adjacent donor projectiles in Tests A1 and A3 was clearly a "worst cast" threat condition. The fragment jet produced the equivalent of a giant "karate chop" along the centerlines of the test bed surfaces. For the M107 detonations of Test A1, the fragment jet cut a trench approximately 32 inches (80 cm) wide and 10 inches (25 cm) deep along the top of the sand bed. A shallower trench about 16 inches wide extended across the center of the test bed surface, normal to the trench from the fragment jet. The four quadrants (each measuring about 5 by 6 ft) outside the trenched areas each contained an average of about four to five "normal" fragment impacts distributed randomly over the quadrant areas (see Figure 16a). The term "normal" implies that these fragments were not affected by any interaction between the munitions.

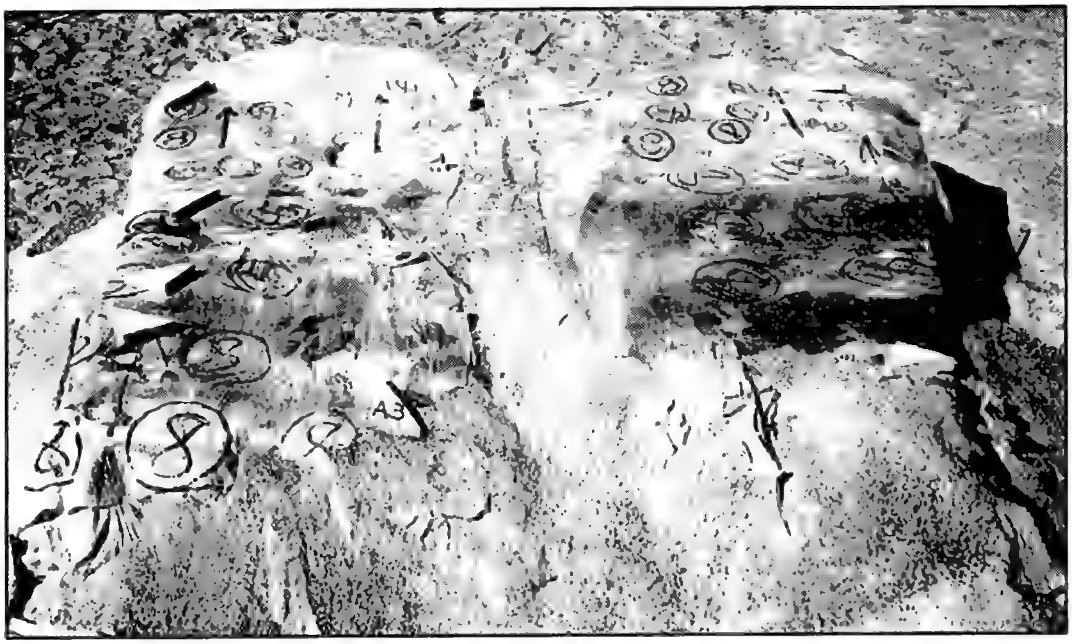
After each test, the 4-inch sand layers were removed one by one, and the number of fragment holes in each sheet of plastic between the layers was counted and mapped (Figure 16b). Below the trench from the fragment jet, 8 to 10 fragments were found in the fourth sand layer (third layer in Test A2), and two in the layer below. The normal fragments in the four quadrants penetrated only into the second layer on Test A1, and the third layer on Test A3.

In Test A2 with the 155-mm M107 projectile, the single piece of sheet metal above the test bed appeared to reduce the depth of the fragments below the trench slightly, but the normal fragments in the quadrants penetrated slightly deeper. In Test A4 with the 105-mm projectile and the two layers of sheet metal panel, the fragment penetrations below the trench were slightly deeper, but unchanged in the quadrants. In both tests, however, large pieces of the sheet metal were blown into the sand bed. The smaller fragments penetrated down to the sixth layer in Test A2, and into the third layer on Test A4. Table 7 details the number of fragments recovered and their penetration depths into the sand layers for the Test A series.

The maximum fragment penetration depth of 20 inches (50 cm) for a 155-mm projectile fragment from Test A1 was used to define a curve of fragment velocity as a function of penetration depth into sand. Figure 17 illustrates this relation. From the FRAGPROP computer model, the maximum fragment impact velocity (V_i) into a sand layer located 8.0 ft from a detonation of a 155-mm M107 projectile is 3,380 ft/sec. Using the maximum penetration depth (D_{max}) of 20 inches from the Test A series, the velocity of a "standard" M107 fragment at any depth (D) along its penetration path can be calculated from the equation:

$$V = V_i \sqrt{1 - D / D_{\max}}$$

Figure 17 shows a plot of this function for the M107 fragments. Previous research indicates that the critical (minimum) impact velocity of a fragment against an acceptor M107 round that can cause a detonation is approximately 550 ft/sec. The curve indicates that the velocity of a standard M107 fragment will fall below this critical value after penetrating approximately 19 inches of



a. Fragment damage to witness sheet at Layer 8, below top four in. of sand

b. Sand surface below Layer 7 witness sheet (arrow points to a single fragment embedded in the sandbed)

Figure 16. Penetration of fragments into sandbed from Test A3

Table 7
Test A Series: Fragment Penetration Depths in Sand Testbed

	Fragment Jet	Normal Fragments	Wall Panel Fragments
Test A1 (155-mm pair, no container wall):			
0 – 10 cm[a]	Many	10	--
10 - 20 cm	Many	0	--
20 - 30 cm	Many	0	--
30 – 40 cm	~10	0	--
40 – 50 cm	2	0	--
50 – 60 cm	0	0	--
Test A2 (155-mm pair, single container wall panel[b]):			
0 – 10 cm[a]	Many	1	1
10 - 20 cm	Many	10	7
20 - 30 cm	~10	2	2
30 – 40 cm	5	0	2
40 – 50 cm	0	0	0
50 – 60 cm	0	0	1
Test A3 (155-mm pair, no container wall[b]):			
0 – 10 cm[a]	Many	8	--
10 - 20 cm	Many	11	--
20 - 30 cm	Many	2	--
30 – 40 cm	~8	0	--
40 – 50 cm	2	0	--
Test A4 (155-mm pair, container panels[c]:			
0 – 10 cm[a]	Many	6	3
10 - 20 cm	Many	10	2
20 - 30 cm	Many	2	2
30 – 40 cm	~10	0	0
40 – 50 cm	5	0	0
50 – 60 cm	5	0	0

[a] Test bed surface was 8 ft (2.5 m) below horizontally-oriented munition pairs.
[b] Located 2.0 ft (60 cm) above testbed surface.
[c] One located 2.0 ft above testbed surface, the other 2.0 ft below the munitions.

From FRAGPROP (ARL):

Initial Fragment Velocity
V_i = 3,380 ft/sec

From Tests A1 and A3:

Max. Fragment Penetration Depth
D_{max} = 20 inches

From Penetration Equation:

Reduced Fragment Velocity After Penetrating a Sand Thickness, D

$$V = V_i\,(1 - D/D_{max})^{1/2}$$

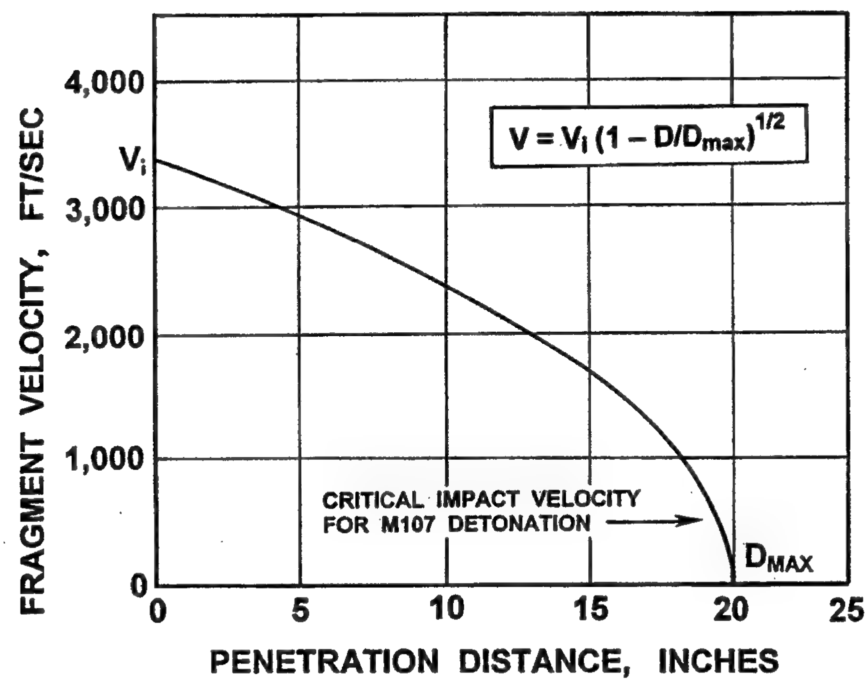


Figure 17. Calculation of residual velocity of standard fragments from 155-mm M107 HE-loaded projectiles as a function of penetration distance into sand-filled barricades.

sand. Therefore, a sand barricade 18 in. thick, together with the sheet metal sidewall of an acceptor container (from FRAGPROP calculations in Phase 1), should be sufficient to prevent propagation to an acceptor container of M107 rounds from the detonation of a similar donor located 8 ft from the barricade. **Note**: *The fragment jet from the simultaneous detonation of the 105-mm pair of munitions in Test A4 penetrated slightly deeper, but since HD 1.2 munitions should not detonate* en mass, *only the "normal" fragment data from the 105-mm tests should be used.*

These calculations were the basis for selecting the 18-inch (45-cm) thickness of the "thin" barricade tested in Test C.

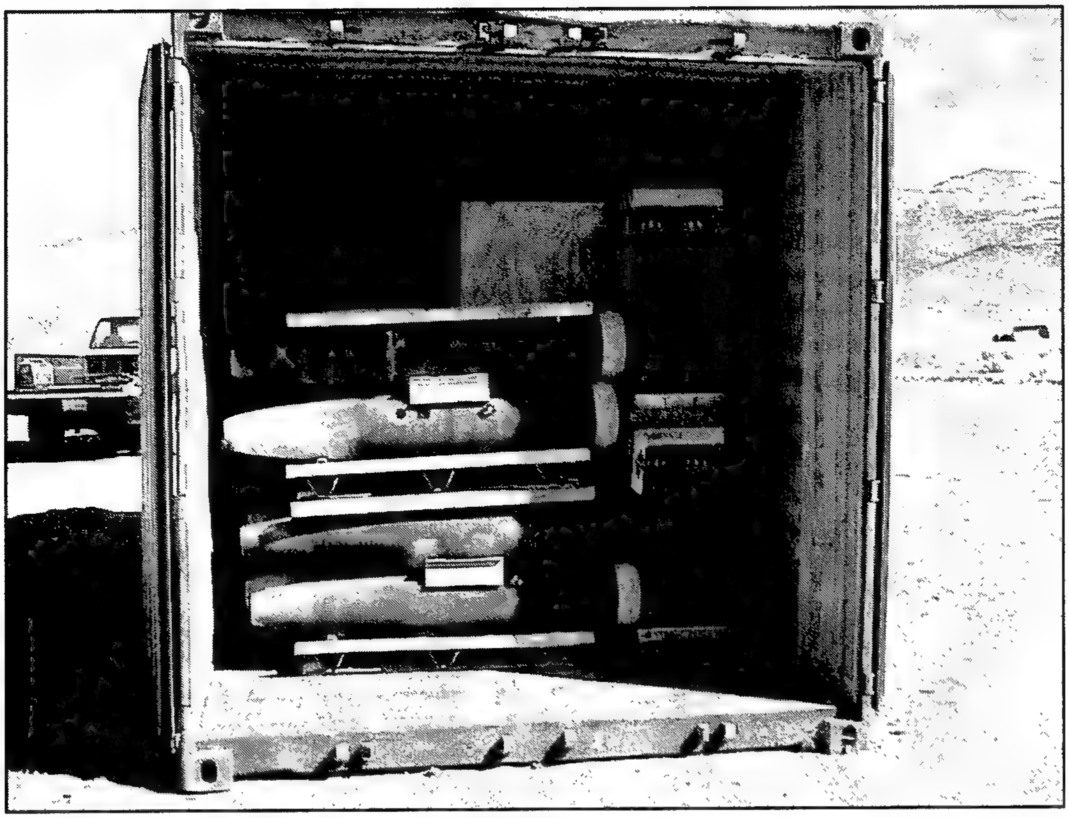
Test Series B

Test B1. This test was performed to validate the conclusion that an acceptor container of munitions will not detonate when subjected to airblast loads equivalent to the impact shock load experienced by the same loaded container in a 40-ft drop test. The donor source was 2,200-lbs of flake TNT located 26 ft from the acceptor ISO container. The acceptor contained two pallets each of unfuzed M107 projectiles (16 rounds), M2 demolition shaped charges, M67 hand grenades (300 rounds) and 155-mm M864 munitions (16 rounds). Figure 18 shows the acceptor container and test set-up.

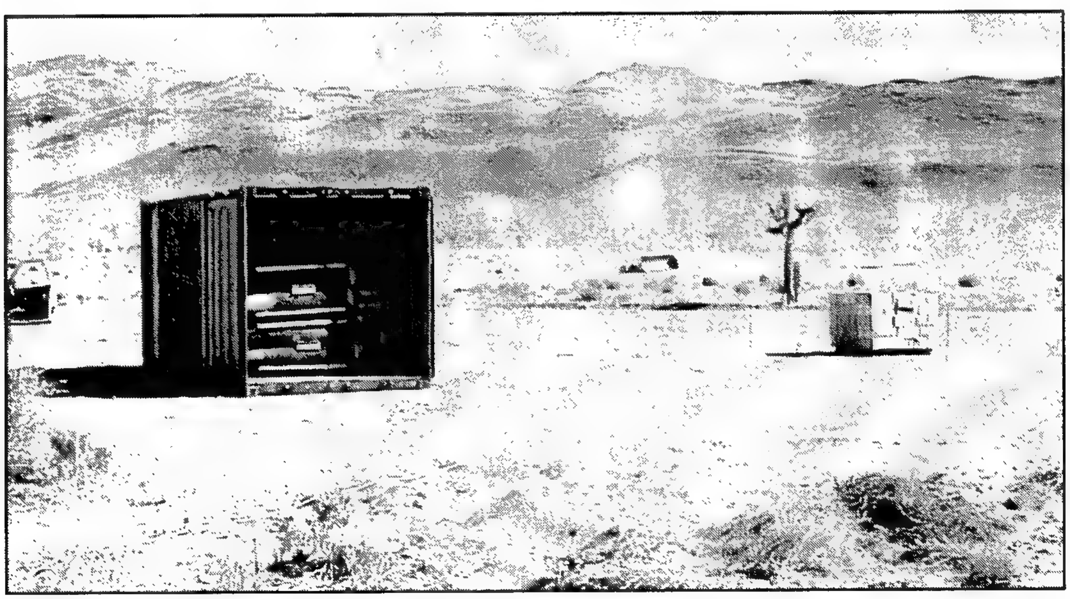
The M2 demolition shaped charges were designated by ARL as a probable "worst case" acceptor with regard to sensitivity to initiation by shock loads. In Test B1, the M2's clearly demonstrated their qualification for this designation. An analysis of the witness plate data and high-speed video shows that the M2's were initiated by the donor airblast and that they, in turn, initiated the M107 acceptor projectiles nearby.

Figures 19-21 shows the postshot results of Test B1. The 2,200-lb donor charge detonation formed a crater approximately 10 ft (3 m) in diameter and 4.5 ft (1.4 m) deep in the dry sandy soil. A smaller crater was formed by the detonation of the M2 demolition shaped charges and the M107 rounds in the acceptor container, which was completely destroyed. Not all of the M864 rounds detonated. Several were found scattered out to 300 ft (90 m) from the original acceptor location, with some split open and their contents exposed. M107 fragments were found as far as 2,000 ft (600 m) from the container location. Most of the M67 hand grenades were recovered around the shot area, with three found in the acceptor crater.

Test B2. The examination of the Test B1 results clearly showed that the M2 demolition shaped charges were the source of the B1 acceptor container detonation. Since these munitions are extremely sensitive to shock-induced detonation, it was decided to repeat Test B1, but with the M2 shaped charges replaced by 105-mm HE projectiles. This was Test B2.



a. Acceptor munitions, backed by inert MK-81 bombs



b. Acceptor container (left) and donor charge (right)

Figure 18. Set-up for Test B1

a. View from donor location (note acceptor container in distant background, to left of center)

b. Acceptor debris

Figure 19. Post-detonation photos from Test B1

a. Intact and burned munitions

b. Crater from M2 shaped charge detonation

Figure 20. Acceptor reactions from Test B1

a. Damaged M864 submunitions

b. Burned 105mm projectile

Figure 21. Damaged acceptors from Test B1

Test B2 was clearly successful, in that no detonations of the munitions in the acceptor container occurred. The container itself was completely destroyed by the donor airblast, and the munitions were scattered over a small area. Some of the acceptor rounds were broken up by the blast and burned. A small fire resulted in the pile of munitions left by the blast, causing cook-off detonations of several 155-mm M107 and 105-mm HE projectiles. The cook-off detonations began about five minutes after the donor event, and continued intermittently for about 15 minutes. Since there was no prompt detonation of the acceptors, however, and the late-time cook-off detonations did not contribute to the total MCE of the donor detonation, Test B2 was considered a successful validation of the 3.0 ft/lb$^{1/3}$ (1.0 m/kg$^{1/3}$) separation distance as a minimum IMD to prevent prompt propagation between containers by airblast effects.

Test C

Barricade Construction. One of the objectives of Test C was to evaluate the ease of construction of a Blast-Tamer barricade. The two 10m-long barricades were easily set up in one day by three workers who had no previous experience in barricade construction, but under the supervision of a single team leader who did have such experience. Figure 22 shows stages in the construction work, and Figure 23 shows the completed barricades.

The only difficulty encountered was in dumping sand between the wall panels of the slope-sided barricade. In the current barricade design, nylon cords are run through the wall panels and knotted at the outside face of each panel to hold the walls at the correct spacing against the pressure of the sandfill. However, as the sand was dumped between the walls with a front-end loader, the weight of the falling sand deflected the nylon cords downward, pulling the sidewalls inward. It was necessary to reach down inside the barricades and free the cords from the sand so that the sand pressure could push the panels back out to their proper spacing.

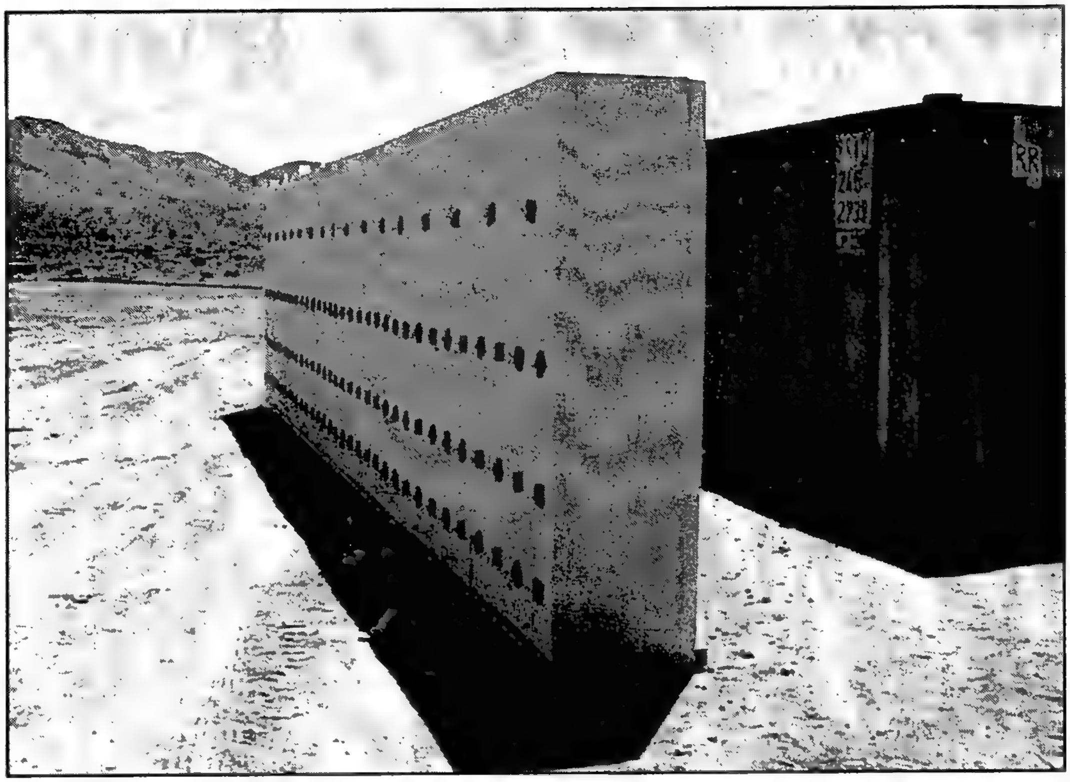
Slope-sided Barricade Performance. Figure 24 shows the donor and acceptor containers prepared for Test C. The detonation sequence for Test C is shown in Figure 25. At –2 msecs (before the donor initiation), the flash of the detonating cord can be seen just before it enters the donor container. Figure 26 follows the motion history of the blast front as it breaks out of the donor container, sweeps over the slope-sided barricade, and displaces the acceptor container. The shape of the blast front and the movement of the front and back sides of the acceptor container clearly show that the blast load had a strong downward component after it bent over the barricade and struck the top of the container.

The post-test condition of the ammunition and container protected by the slope-sided barricade is shown in Figures 27 and 28. The barricade itself was completely blown away, with only some of the plywood floor panels left in

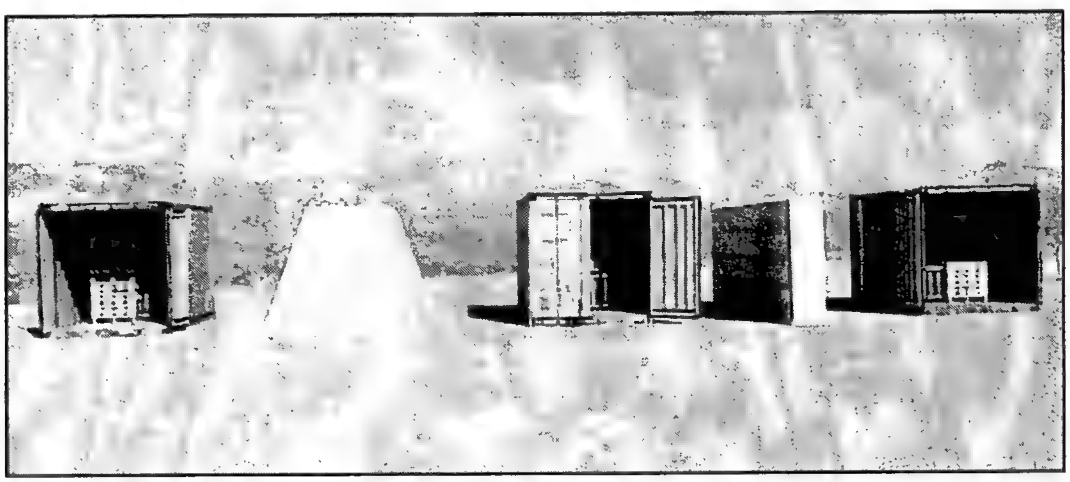
a. Erecting wall panels

b. Dumping sand into wall enclosure

Figure 22. Construction of Blast-Tamer barricade with sloping sides

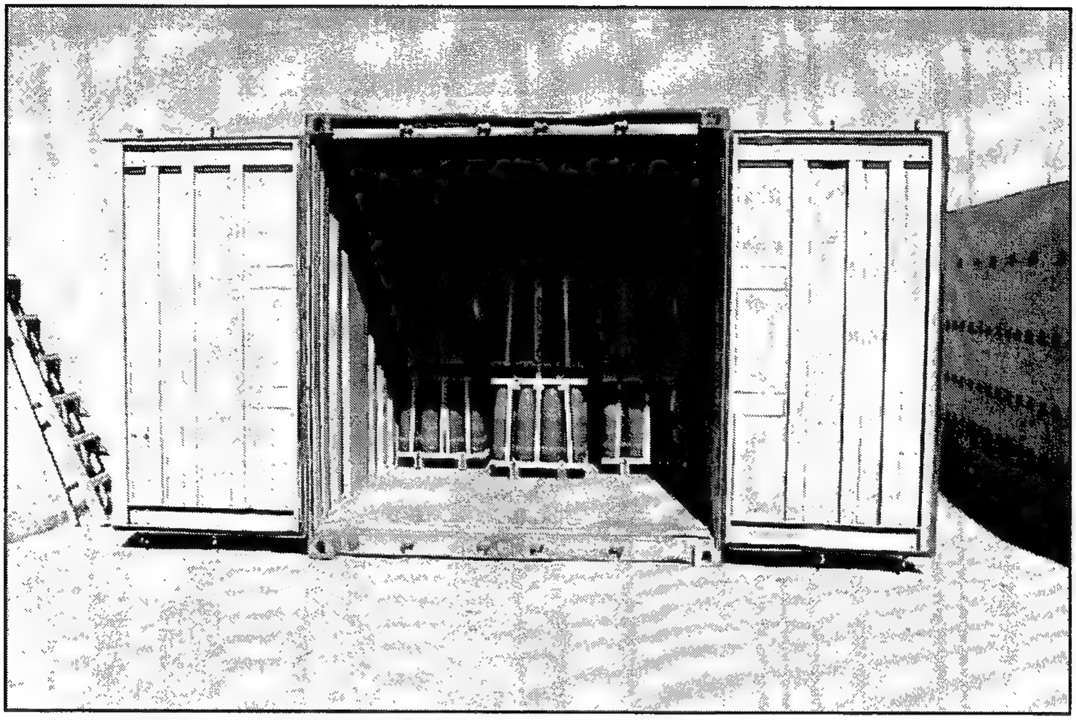


a. 0.5-m-thick Blast-Tamer barricade, with donor container at right

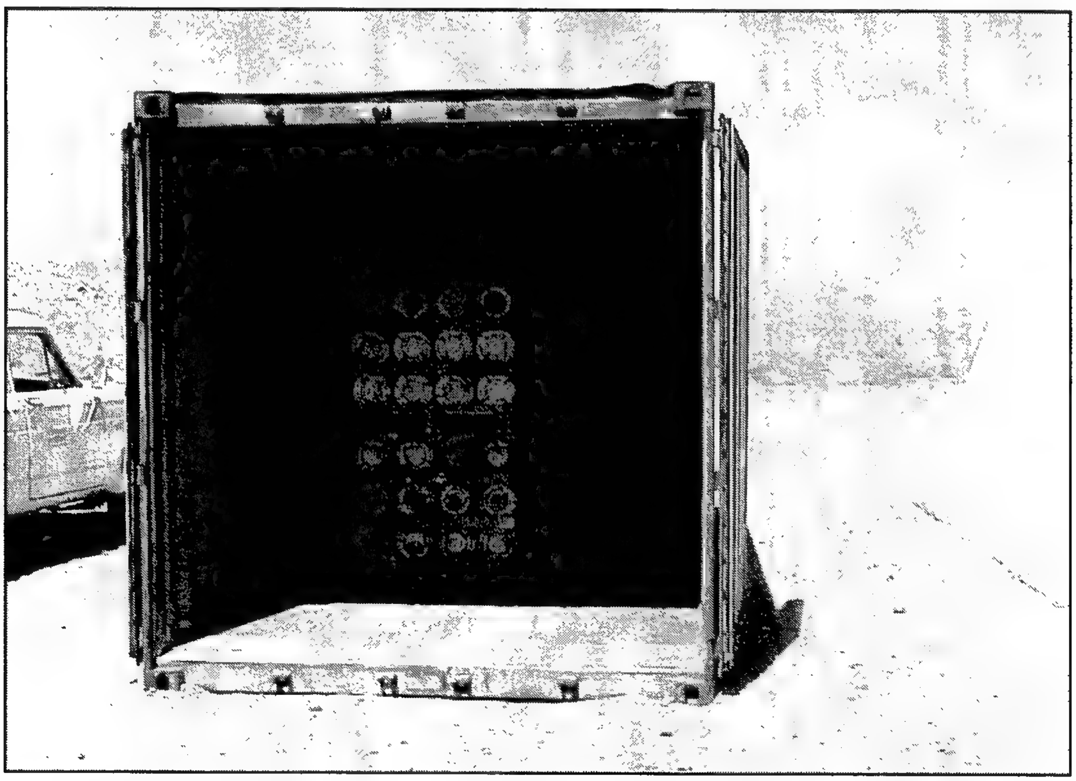


b. Completed barricades and donor (center) and acceptor containers ready for test

Figure 23. Test C, with 155mm M107 projectiles in donor and acceptor containers



a. Donor container with 6,200-lb NEW of M107 projectiles



b. Acceptor container with M107 projectiles on right side, backed by inert MK-81 bombs on left side (donor is to the right of picture)

Figure 24. Donor and acceptor containers for Test C

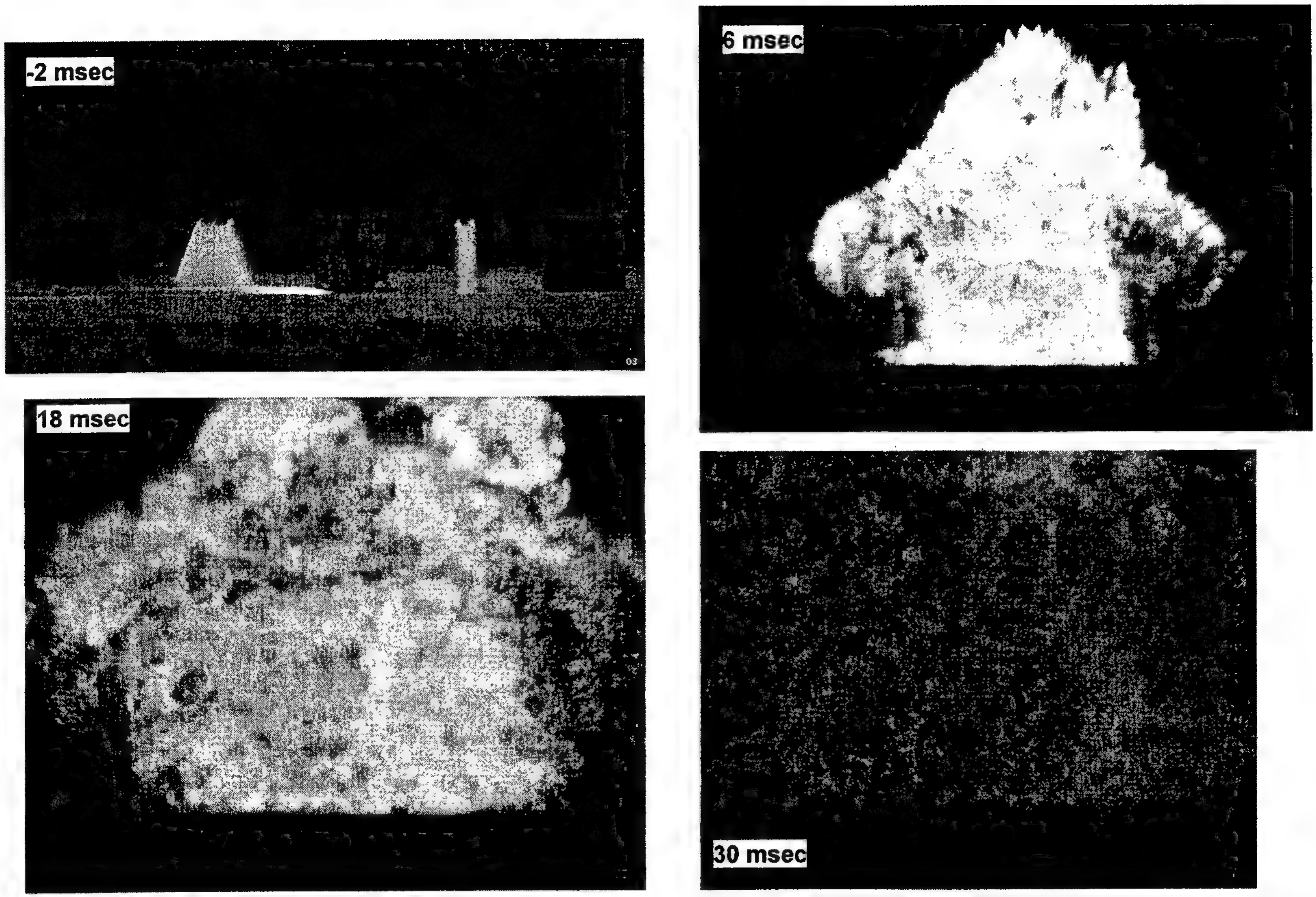


Figure 25. Detonation sequence for Test C (Note detcord flash from detonating cord between slope-sided barricade and donor container at 2 msec before detonation, in upper left photo)

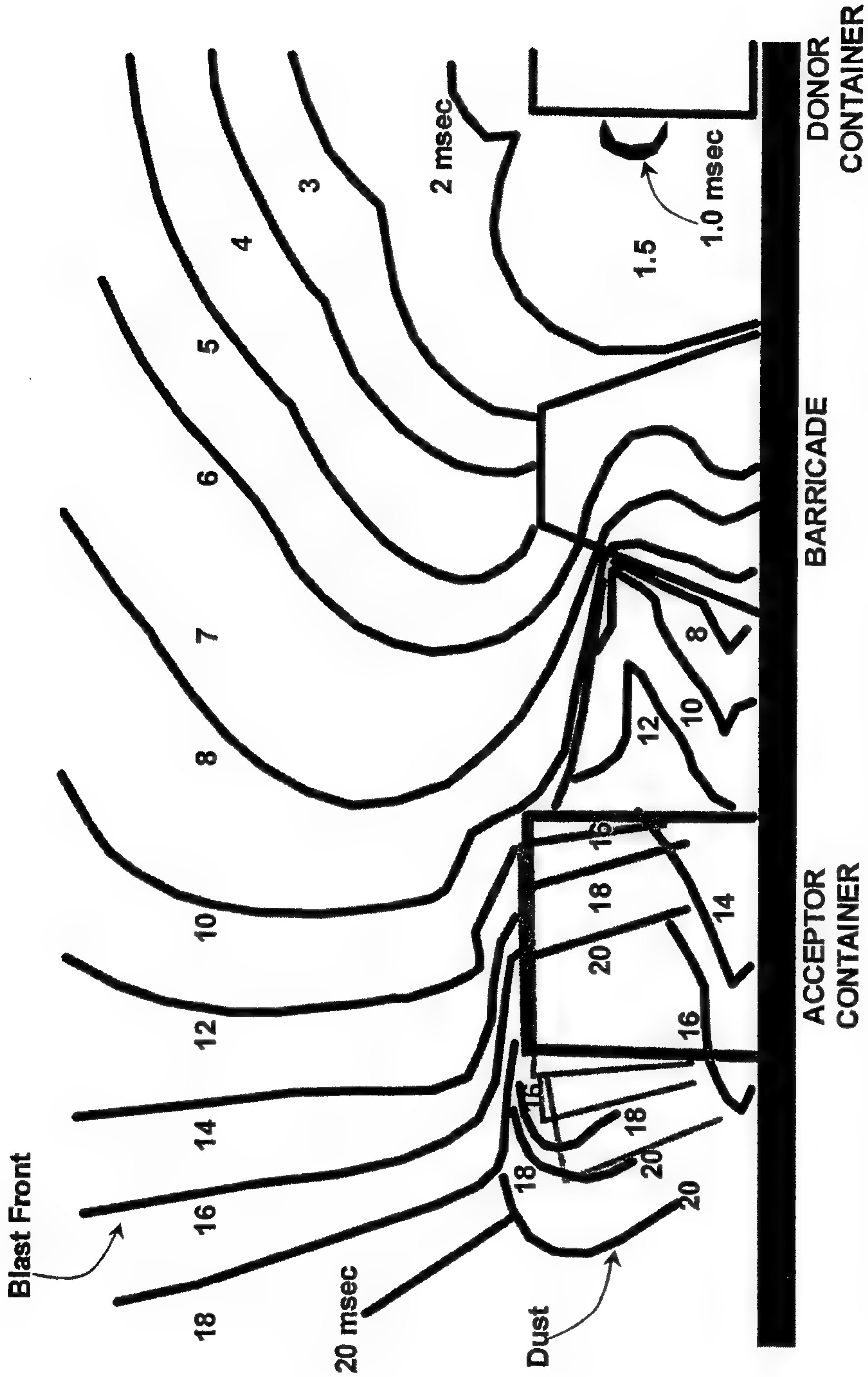
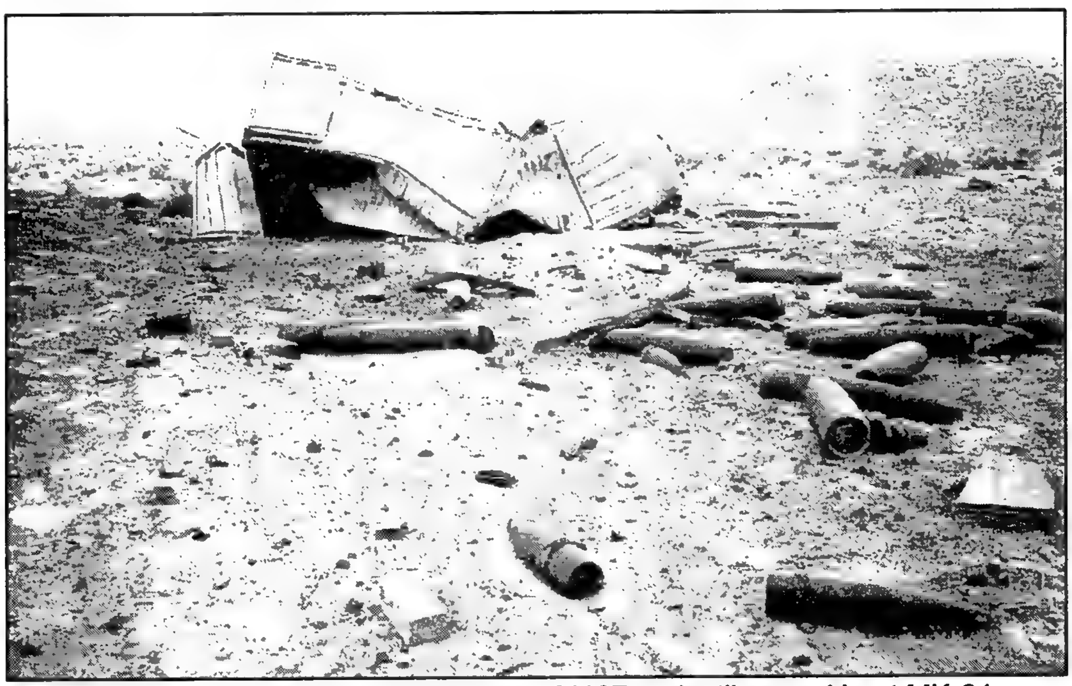


Figure 26. Motion history of blast front across slope-sided barricade, Test C

a. Donor crater in foreground, pieces of slope-sided barricade base beyond that, and container and spilled munitions in background



b. Close-up view of damaged container, M107 projectiles, and inert MK-81 bombs

Figure 27. Damage to acceptor container protected by slope-sided barricade from Test C

a. View looking toward detonation point (behind container); container is oriented upside-down, doors to right

b. Close-up of container interior and acceptor munitions (M107's and inert MK-81 bombs)

Figure 28. Damage to acceptor container protected by slope-sided barricade

place. The container was blown about 30 m and badly mangled. The M107 acceptor rounds were scattered from 20 m in front to 20 m behind the container, and many rounds were jumbled around inside the container.

None of the 32 acceptor rounds were seriously damaged. An inspection revealed no dents or gouges—only small scratches from the tumbling of the container. No charring or other evidence of heat effects was found on the container, the munitions, or the wood munition pallets.

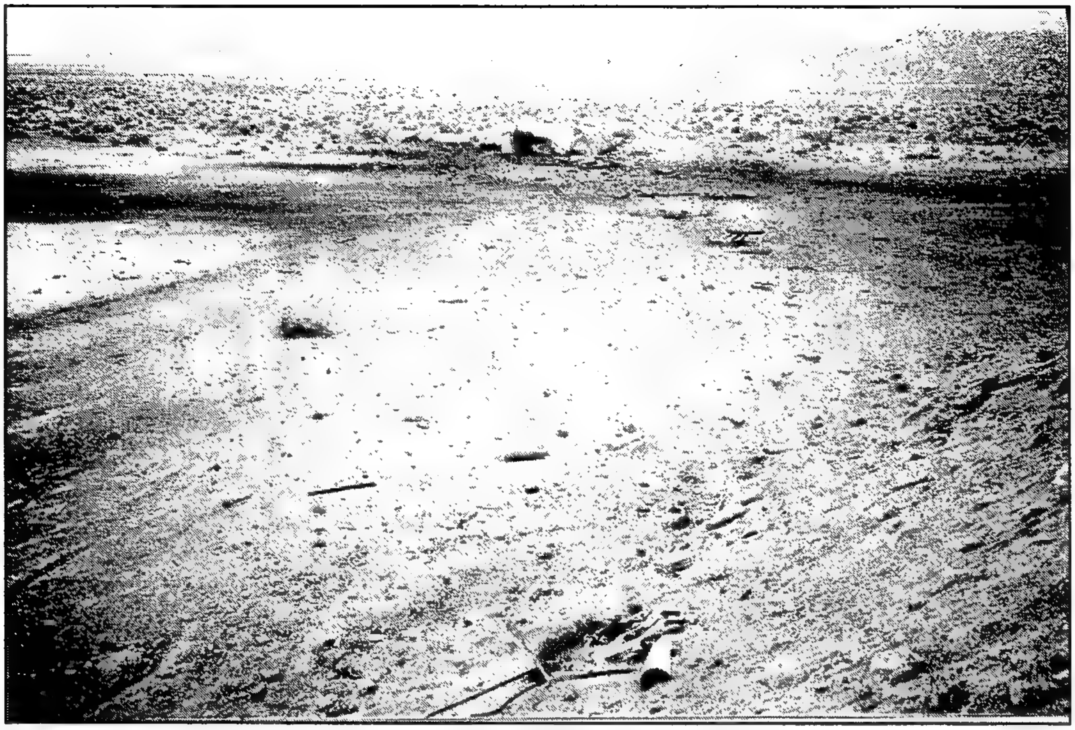
While the slope-sided barricade may have deflected some of the blast from the donor detonation upward, this effect was not evident in the detonation photography. The average barricade thickness of 1.5 m provided a large inertial resistance to the initial blast front, forcing it to bend over the top of the barricade. The retarding of the blast force, along with the downward component of the blast impact, greatly reduced the dynamic load on the acceptor container. Based on the essentially undamaged condition of the M107 acceptor projectiles, it appeared that this barricade design offers a high degree of protection against propagation when placed in the middle of a 6.5 m separation distance between donor and acceptor containers of robust munitions.

Thin-walled Barricade Performance. The thin-walled barricade had only half the average thickness and mass of either the slope-sided barricade or a standard Hesco-Bastion barricade. While this was not sufficient to keep the acceptor container from being blown apart, the acceptor munitions received only minor damage at a 5.5 m separation distance between containers.

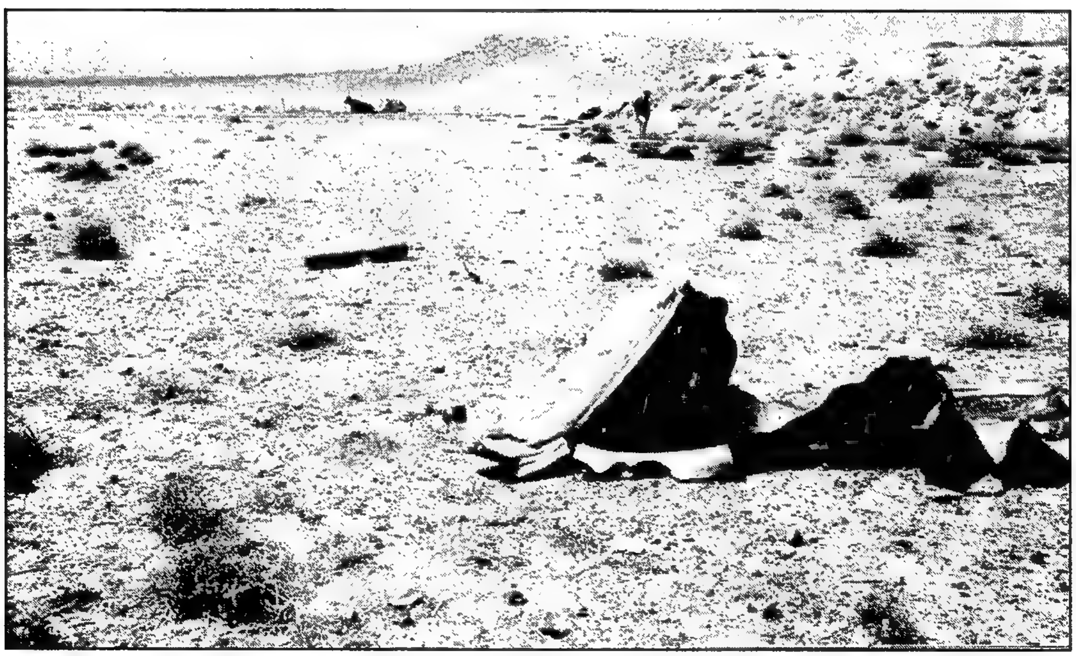
The container protected by the thin barricade suffered much more damage, as expected. The container itself was completely blown apart, with pieces scattered up to 120 m from the original location. The largest piece of the container found was only about 2 m square (Figure 29).

The projectiles from this acceptor were scattered over a distance of 30 to 80 m from the blast. Surface scratches were clearly evident, and the brass rotator bands were crushed at round-to-round contact points. No dents, gouges, or other damage was found. Multiple dents were found, however, on several of the inert MK-81 bombs that were used to back the M107 projectiles. The MK-81's had been stacked horizontally behind the vertically-arranged M107's, and the dent spacings on the MK-81's corresponded to the M107 spacings on their pallets. Figure 30 shows a typical example. The dents ranged up to approximately one centimeter in depth.

Many M107 fragments from the donor container were dispersed over the area containing the acceptor container debris and the scattered acceptor munitions. Although half of the 32 M107's in the acceptor container were directly exposed to any fragments that would have passed through the thin barricade and the container sidewall, none were found to have any marks indicating fragment impacts. Small pieces of the Blast-Tamer barricade



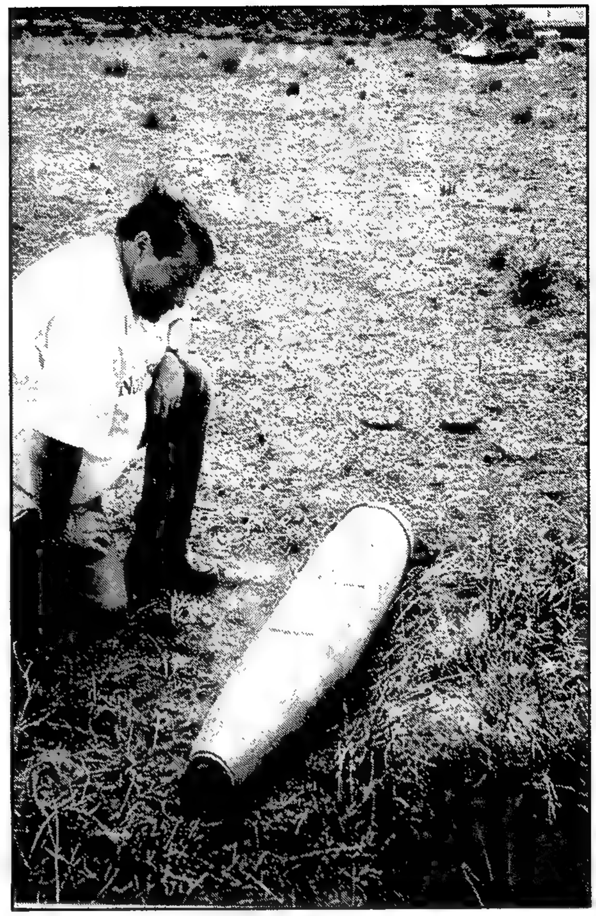
a. Spilled munitions from container in foreground, detonation crater and container protected by slope-sided barricade in background



b. Piece of container and an inert MK-81 at 120-m-range

Figure 29. Damage to acceptor container protected by thin barricade, Test C

a. M107 projectile at 45m, with broken brass rotator band (Note piece of container and inert MK-81's in background at about 60 m)



b. Dented inert MK-81 at about 120 m (Note piece of container at upper right)

Figure 30. Posttest condition of munitions from acceptor container protected by thin barricade, Test C

were distributed over the area. Most of these ranged from about 5 to 30 cm in diameter.

The results indicate that, for a scaled separation distance of 0.4 $m/kg^{1/3}$ between donor and acceptor containers, the thin-walled barricade does not have enough mass to prevent some crushing damage between acceptor rounds. This could pose a risk of a detonation of crush-sensitive munitions. For the vast majority of HD 1.1 and 1.2 munitions, however, a sand-filled barrier only one-half-meter thick appears to be sufficient to prevent propagation between closely-space ISO containers of ammunition in temporary storage.

Table 8 compares the barricade performance in Test C with three other recent experiments involving Hesco-Bastion barricades: the test conducted in Denmark in 1998 (Reference 11), a test at Woomera, Australia in 1999 (Reference 14), and a test by ARL in 1999 (Reference 15).

Table 8
Performance Comparisons for Sand-Filled Barricades

Test	Denmark	Woomera	Test C (SS)[a]	Test C (T)[a]	ARL
Barricade type	Hesco-Bastion	Hesco-Bastion	Blast-Tamer	Blast-Tamer	Hesco-Bastion
Barricade thickness	2m	2m	1.5m[b]	0.5m	2m
Donor NEQ	1,000 kg	40,000 kg	2,800 kg	2,800 kg	3,900 kg
Donor-acceptor separation distance	6m	28m	6.5m	5.3m	7m
Scaled separation distance, $m/kg^{1/3}$	0.60	0.82	0.50	0.38	0.45
Calculated impulse w/o barricade, Mpa-msec	18	33	35	43	38
Acceptor container displacement	2m	65m	30m	100m	?
Acceptor munition condition	Good[c]	Good	Good	Minor Damage	Good

a (SS) = slope-sided barricade; (T) = thin barricade.
b Thickness at mid-height.
c Based on expert opinion (no acceptors were actually present).

6 Conclusions

The principal conclusions developed from the analysis and experiments performed in this study were:

- IBD and PTR distances for ISO containers with HD 1.1 components are the same as in open storage.
- FRAGPROP calculations indicate that IMD between containers with fragment-producing HD 1.1 components may be reduced slightly by the reduction of fragment impact velocities due to the shielding effect of acceptor container walls.
- IMD's for containers with non-fragmenting HD 1.1 components can be reduced by significant amounts—down to a scaled separation of 3.0 ft/lb$^{1/3}$(1.0 m/kg$^{1/3}$)—*if there are no highly sensitive munitions (such as M2 demolition shaped charges) in the container loads.*
- IBD, PTR, and IMD values for HD 1.2 munitions in containers (with no HD 1.1 components) are significantly less than indicated by the current standards, according to FRAGPROP calculations. Again, however, the container walls provide only a minor shielding effect, at best, for acceptor munitions.
- The IMD for HD 1.3 material is limited to that necessary to prevent initiation by spread of a fire. Since the containers shield their contents against firebrands, the recommended minimum IMD is 8 ft, for inspection and fire control access.
- "Blast-Tamer" barricades can be easily and quickly constructed by 3 or 4 workers with minimal training. It should also be possible to dis-assemble this type of barricade and re-construct it elsewhere.
- The slope-sided barricade design did not appear to provide any advantage in blast protection over a normal barricade with vertical sidewalls, except for better stability.
- The use of sand-filled barricades allows ISO containers of HD 1.1 munitions to be spaced at IMD's of 20 feet (6 m).
- Barricades with a sand thickness of only 18 inches (0.5 m) are effective in preventing fragment damage between ISO containers of HD 1.1 munitions.

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Appendix A :
U.S. Army Strategic Configured Ammunition Loads

COMPONENTS, QUANTITIES, AND QD'S (FROM CURRENT STANDARDS OF U.S. ARMY STRATEGIC ONFIGURED LOADS (SCL'S)

SCL # 1 ARMOR, 120mm PKG A

SCL # 1

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1315-01-361-5023	C792	CARTRIDGE, 120MM, APFSDS-T, M829A2 IN PA116 CONT	1.2.1	C	8 Plts	200 ea	3979	3979.3	59.7
1315-01-333-0533	C791	CARTRIDGE, 120MM, HEAT-MP-T, M830E1, IN MTL 25MC	1.2.1	E	2 Plts	50 ea	1010	1009.5	60.6

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.2.1	4989	4989	60.6	978	587	200	352

SCL # 2 ARMOR, 120mm PKG B

SCL # 2

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1305-00-892-2150	A131	CTG 7.62MM	1.4	S	2 Plts	57600 rds	386	0.0	
1305-00-028-6466	A576	CTG .50 CAL API M8 API-T M20	1.4	G	1 Plts	10680 rds	359	0.0	
1315-01-361-5023	C792	CARTRIDGE, 120MM, APFSDS-T, M829A2 IN PA116 CONT	1.2.1	C	4 Plts	100 rds	1990	1989.7	59.7
1315-01-333-0533	C791	CARTRIDGE, 120MM, HEAT-MP-T, M830E1, IN MTL 25MC	1.2.1	E	4 Plts	100 rds	2019	2019.0	60.6
1330-01-171-8869	G826	GRENADE,LAUNCHER,SMOKE,IR SCREENING,M76	1.2.2	G	2 Plts	768 ea	59	59.1	0.0

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.2.1	4813	4009	60.6	942	565	200	339.12

SCL # 3 ENGINEER, BREACHING

SCL # 3

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1365-00-939-6599	K869	SMOKE POT, FLOATING SGF 2 AN-M7	1.4	G	1 Plts	33 ea	25248	0.0	
1375-00-724-7040	M023	CHG, DEMO BLOCK M112 1 1/4 LB COMP C-4	1.1	D	2 Plts	2160 ea	2700	2700.0	
1375-00-926-1948	M028	DEMO KIT, BANGALORE TORP M1A2	1.1	D	2 Plts	32 ea	3430	3430.4	
1375-00-756-1865	M130	BLASTING CAP, ELEC.M6	1.4	B	1 Cntr	900 ea	2	0.0	
1375-00-028-5228	M131	CAP BLASTING NON-ELEC M7	1.1	B	1 Cntr	500 ea	1	1.0	
1375-00-088-6691	M421	CHG, DEMO SHAPED M3 SERIES 40 LB	1.1	D	2 Plts	48 ea	1440	1440.0	
1375-00-204-0851	M456	CORD, DET, PETN TYPE 1 CL E (NEW=1000 ft)	1.1	D	2 Plts	72000 ft	504	504.0	
1375-00-028-5246	M670	FUZE, Blasting, Time M700	1.4	S	1 Bxs	4000 ea	11	0.0	
1375-00-529-9032	M766	IGNITER, M2/M60 F/TIME BLASTING FUZE	1.4	S	2 Bxs	500 ea	0	0.0	
1375-00-926-3985	M757	CHG, ASSY DEMO M183 COMP C-4 8X2 1/2 LB	1.1	D	1 Plts	72 Chgs	1440	1440.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	34776	9515	9515	1250	750	233	381

SCL # 4 ENGINEER, MICLIC

SCL # 4

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1340-01-118-2838	J143	ROCKET MOTOR, 5 IN MK22 MOD 4 (FOR MICLIC)	1.3	C	1 Plt	6 Rkts	276	276.3	
1340-01-118-2838	J143	ROCKET MOTOR, 5 IN MK22 MOD 4 (FOR MICLIC)	1.3	C	3 Bxs	3 Rkts	138	138.1	
1375-01-133-4189	M913	CHG, DEMO HE LINEAR M58A3 (MICLIC)	1.1	D	6 Plt	6 ea	10500	10500.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	10914	10914	10914	1250	750	244	399

SCL # 5 ENGINEER. DEMOLITION

SCL # 5

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1375-00-724-7040	M023	CHG, DEMO BLOCK M112 1 1/4 LB COMP C-4	1.1	D	1 Plts	1080 Chgs	1350	1350.0	
1375-00-728-5941	M024	CHG, DEMO BLOCK M118 2LB PETN	1.1	D	1 Plts	480 Chgs	960	960.0	
1375-00-028-5142	M032	CHG, DEMO BLOCK TNT 1 LB	1.1	D	1 Plts	1152 Chgs	1152	1152.0	
1375-01-250-6029	M039	CHG, DEMO BLOCL 40 LB CRATERING	1.1	D	1 Plts	50 Chgs	7022	2021.5	
1375-01-192-9174	M130	BLASTING CAP, M6	1.1	B	8 Cntrs	1080 ea	3	3.1	
1375-01-315-1335	M131	CAP BLASTING NON-ELEC M7 (Improved Packaging)	1.1	B	24 Cntrs	1000 ea	3	2.8	
1375-00-028-5171	M241*	DESTRUCTOR, Expl UNIVERSAL M10	1.1	D	1 Plts	900 ea	258	257.7	
1375-00-028-5237	M420	CHG, DEMO SHAPED M2 SERIES 15 LB	1.1	D	1 Plts	60 Chgs	690	690.0	
1375-00-088-6691	M421	CHG, DEMO SHAPED M3 SERIES 40 LB	1.1	D	1 Plts	24 Chgs	720	720.0	
1375-00-204-0851	M456	CORD, DET, PETN TYPE 1 CL E (NEW=1000 ft)	1.1	D	1 Plts	36000 ft	252	252.0	
1375-00-028-5246	M670	FUZE, Blasting, Time M700	1.4	S	1 Plts	24000 ft	64	0.0	
1375-00-926-3985	M757	CHG, ASSY DEMO M183 COMP C-4 8X2 1/2 LB	1.1	D	1 Plts	72 Chgs	1440	1440.0	
1375-00-529-9032	M766	IGNITER, M2/M60 F/TIME BLASTING FUZE	1.4	S	1.5 Plts	3750 ea	2	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	13915	8849	8849	1250	750	228	372

SCL # 6 **ENGINEER, VOLCANO MINE**

SCL # 6

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1345-01-233-2029	K045	MINE. CANISTER HE XM87 (VOLCANO)	1.1	D	10 Plts	400 Mines	3039	3039.2	
1345-01-233-2029	K045	MINE. CANISTER HE XM87 (VOLCANO)	1.1	D	9 3/4 Plts	288 Mines	2188	2188.2	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	5227	5227	5227	1250	750	191	312

SCL # 7 **ARTILLERY, 155mm**

SCL # 7

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1320-00-143-6847	D533	CHARGE, PROPELLING 155MM WHITE BAG M119	1.3	C	1 Plts	30 Chgs	627	627.5	
1320-00-028-4878	D541	CHARGE, PROPELLING 155MM M4	1.3	C	3 Plts	150 Chgs	2038	2038.1	
1320-00-872-3164	D563	PROJECTILE, 155MM, M483, M483A1 ON WOOD PALLET N N	1.1	D	21 Plts	168 Rds	1000	1000.5	
1390-01-282-6038	N289	FUZE, ELECTRONIC TIME	1.4	S	1 Plts	576 Fzs	0	0.0	
1390-00-892-4202	N523	PRIMER, PERC M82	1.4	G	1 Bx	500 Prmrs	2	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	3668	3666	3666	1250	750	170	278

SCL # 8 **ARTILLERY, 155mm EX Range**

SCL # 8

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1320-00-143-6847	D533	CHARGE, PROPELLING 155MM WHITE BAG M119	1.3	C	4 Plts	120 Chgs	2510	2509.9	
1320-00-143-6847	D533	CHARGE, PROPELLING 155MM WHITE BAG M119	1.3	C	4 Shrt Plts	72 Chgs	1506	1506.0	
1320-01-231-1697	D864	PROJECTILE, 155MM, EXTENDED RANGE, DP, M864	1.1	D	24 Plts	192 Rds	1421	1420.8	
1390-01-282-6038	N289	FUZE, ELECTRONIC TIME	1.4	S	12 Cntrs	192 Fzs	0	0.0	
1390-00-892-4202	N523	PRIMER, PERC M82	1.4	G	1 Bx	500 ea	2	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	5438	5437	5437	1250	750	193	317

SCL # 9 **ARTILLERY, 155mm Smoke**

SCL # 9

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1320-01-231-1697	D528	PROJECTILE, 155MM, EXTENDED RANGE, DP, M864	1.1	D	21 Plts	168 Rds	1243	1243.2	
1320-00-143-6847	D533	CHARGE, PROPELLING 155MM WHITE BAG M119	1.3	C	4 Plts	120 Chgs	2510	2509.9	
1320-00-028-4878	D541	CHARGE, PROPELLING 155MM M4	1.3	C	3 sht P;ts	90 Chgs	1223	1222.8	
1390-00-805-0692	N285	FUZE, MTSQ M577/577A1 W/O BOOSTER	1.4	D	1 lt Plt	192 Fzs	0	0.0	
1390-00-892-4202	N523	PRIMER, PERC M82	1.4	G	1 Bx	500 ea	2	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	4978	4976	4976	1250	750	188	307

SCL # 10 **ARTILLERY, MLRS**

SCL #10

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1340-01-122-3506	H104	ROCKET POD, 298MM TACTICAL M26 (MLRS)	1.1	E	5 Pods	24 Rkts	37645	9290.7	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	37645	9291	9291	1250	750	231	378

SCL # 11 **INFANTRY,Small Arms**

SCL #11

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1305-01-155-5459	A059	CARTRIDGE 5.56MM BALL M855	1.4	S	2 Plt	161280 Rds	611	0.0	
1305-01-155-5457	A063	CARTRIDGE 5.56MM TRACER M856	1.4	S	1 lt Plt	29520 Rds	105	0.0	
1305-01-252-0153	A064	CARTRIDGE 5.56MM	1.4	S	2 Plt	115200 Rds	507	0.0	
1305-00-926-3929	A072	CARTRIDGE 5.56MM	1.4	S	1 Plt	80640 Rds	372	0.0	
1305-00-449-8055	A131	CARTRIDGE 7.62MM	1.4	S	2 Plt	115200 Rds	907	0.0	
1305-01-172-9558	A363	CARTRIDGE 9MM	1.4	S	1 lt Plt	4000 Rds	4	0.0	
1305-00-028-6466	A576	CTG .50 CAL API M8 API-T M20	1.4	G	1 Plt	10080 Rds	339	0.0	
1330-00-219-8511	G930	GRENADE, HAND SMK HC AN/NB	1.4	G	1 Plt	864 Rds	1037	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.4	3881	0	0	100	100	50	50

SCL # 12 **INFANTRY, Misc**

SCL #12

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1305-01-155-5462	A059	CARTRIDGE 5.56MM BALL M855	1.4	S	2 Plts	161280 Rds	574	0.0	
1305-01-156-7584	A064	CARTRIDGE 5.56MM	1.4	S	2 Plts	38400 Rds	169	0.0	
1305-01-172-9558	A363	CARTRIDGE 9MM	1.4	S	1 lt Plts	24000 Rds	22	0.0	
1305-00-028-6466	A576	CTG .50 CAL API M8 API-T M20	1.4	G	2 Plts	20160 Rds	677	0.0	
1305-00-143-7163	A131	CTG 7.62 LINKD	1.4	S	2 Plts	28800 ea	228	0.0	
1330-00-133-8244	G881	GRENADE, HAND FRAGMENTATION M67	1.1	F	1 Plts	1440 Mines	536	535.7	
1345-00-710-6946	K143	MINE, APERS M18A1 APERS M18/T48,W/AC	1.1	D	1 Plts	192	288	288.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	2494	824	824	1250	750	103	169

SCL # 13 **AVIATION, AH-1**

SCL #13

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1305-01-155-3197	B130	CARTRIDGE 30MM M789 HEDP RH LINKED	1.2.2	E	4 Plts	6912 Rnds	1230	406.4	0.0
1340-01-108-8851	H163	ROCKET, 2.75 IN HE W/WHD M151 (HYDRA)	1.1	E	2 Plts	120 Rkts	1133	1132.9	
1340-01-223-9187	H464	ROCKET, 2.75 IN MPSM W/WHD M229 (HYDRA-70)	1.2.1	E	2 Plts	120 Rkts	1105	1104.7	110.5
1410-01-126-4662	PA79	GM, SURF ATTCKK AGM-114A REDUCD SMK (HELLFIRE)	1.1	E	2 Plts	18 GMs	623	254.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD*	ILD*
1.1	4090	2898	2898	1250	750	300	339

* distance for 1.2.1 items

SCL # 14 **AVIATION, AH-1**

SCL #14

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1305-00-143-7034	A653	CARTRIDGE 20MM HEI AND TP-T M56A3/M220 (4/1)	1.2.2	E	4 Plts	9600 Rds	1094	229.3	0.0
1340-01-108-8851	H163	ROCKET, 2.75 IN HE W/WHD M151 (HYDRA)	1.1	E	2 Plts	120 Rkts	1133	1132.9	
1340-01-223-9187	H464	ROCKET, 2.75 IN MPSM W/WHD M229 (HYDRA-70)	1.2.1	E	2 Plts	120 Rkts	1105	1104.7	110.5
1410-01-322-5333	PV18	GM, SURF ATTACK BGM-71F(TOW2B)	1.1	E	3 Plts	3 Rkts	41	40.6	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD*	ILD*
1.1	3372	2508	2805	1250	750	300	328

* distance for 1.2.1 items

SCL # 15 **GENERAL PURPOSE, SAA**

SCL #15

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1305-01-155-5459	A059	CARTRIDGE 5.56MM BALL M855	1.4	S	2 Plts	161280 Rds	611	0.0	
1305-01-155-5457	A063	CARTRIDGE 5.56MM TRACER M856	1.4	S	1 Plts	78720 Rds	280	0.0	
1305-01-252-0153	A064	CARTRIDGE 5.56MM	1.4	S	2 Plts	115200 Rds	507	0.0	
1305-00-449-8055	A131	CARTRIDGE 7.62MM	1.4	S	1 Plts	28800 Rds	227	0.0	
1305-00-028-6466	A576	CTG .50 CAL API M8 API-T M20	1.4	G	2 Plts	20160 Rds	677	0.0	
1310-00-992-0451	B546	CARTRIDGE 40MM HEDP M433 PACKED IN FIBER BOX	1.1	E	2 Plts	3888 Rds	396	395.6	
1330-00-133-8244	G881	GRENADE, HAND FRAGMENTATION M67	1.1	F	1 lt Plts	240 ea	89	89.3	
1345-00-166-6378	K143	MINE, APERS M18A1 APERS M18/T48,W/AC	1.1	D	1 Plts	144 ea	226	226.1	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	3013	711	711	1250	750	98	161

SCL # 16 **GENERAL PURPOSE, 40mm**

SCL #16

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1305-01-156-7584	A064	CARTRIDGE 5.56MM	1.4	S	2 Plts	76800 Rds	338	0.0	
1305-00-449-8055	A131	CARTRIDGE 7.62MM	1.4	S	2 Plts	57600 Rds	453	0.0	
1305-00-449-8055	A131	CARTRIDGE 7.62MM	1.4	S	2 lt Plts	43200 Rds	340	0.0	
1310-01-362-5295	B542	CARTRIDGE 40MM HEDP M430A1	1.1	E	8 Plts	12288	1075	1075.4	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	2207	1075	1075	1250	750	113	184

SCL # 17 **BRADLEY, M2/M3**

SCL #17

NSN	DODIC	NOMENCLATURE
1305-00-449-8055	A131	CARTRIDGE 7.62MM
1305-01-356-0188	A975	CTG 25MM HEI-T M792 W/FUZE PDSD M758
1305-01-092-0428	A974	CARTRIDGE 25MM M791 APDS-T
1330-01-171-8869	G826	GRENADE,LAUNCHER,SMOKE,IR SCREENING,M76
1410-01-322-5333	PV18	GM, SURF ATTACK BGM-71F(TOW2B)

HD		QUANTITY		NEW	NEW/QD	MCE
1.4	S	2 Plts	57600 Rds	453	0.0	
1.2.2	E	6 Plts	15024 Rds	4085	1103.7	24.5
1.4	C	3 Plts	2340 Rds	521	0.0	
1.2.2	G	1 Plts	384 Rds	30	29.6	0.9
1.1	E	2 Plts	24 Rds	325	324.6	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	5413	1458	1458	1250	750	180	296

SCL # 18 **ARMOR, 120mm APFSDS**

SCL #18

NSN	DODIC	NOMENCLATURE
1315-01-361-5023	C792*	CARTRIDGE, 120MM, APFSDS-T, M829A2 IN PA116 CONT
1305-00-028-6603	A576	CTG .50 CAL

HD		QUANTITY		NEW	NEW/QD	MCE
1.2.1	C	10 Plts	300 Rds	5969	5969.0	59.7
1.4	G	4 lt Plts	19200	645	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.2.1	6614	5969	59.7	1007	604	200	363

SCL # 19 **ARMOR, 120mm HEAT**

SCL #19

NSN	DODIC	NOMENCLATURE
1315-01-333-0533	C791	CARTRIDGE, 120MM, HEAT-MP-T, M830E1, IN MTL 25MC
1305-00-028-6603	A576	CTG .50 CAL

HD		QUANTITY		NEW	NEW/QD	MCE
1.2.1	E	10 Plts	300 Rds	6057	6057.0	60.6
1.4	G	4 lt Plts	19200	645	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.2.1	6702	6057	60.6	1010	606	200	328

SCL # 20 **TOW 2A**

SCL #20

NSN	DODIC	NOMENCLATURE
1410-01-322-5333	PV18	GM, SURF ATTACK BGM-71F(TOW2B)

HD		QUANTITY		NEW	NEW/QD	MCE
1.1	E	7 Plts	84 Msls	1136	1135.9	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	1136	1136	1136	1250	750	115	188

SCL # 21 **DRAGON/AT-4**

SCL #21

NSN	DODIC	NOMENCLATURE
1315-01-245-4950	C995	LAUNCHER & CARTRIDGE 84MM M136 AT4
1427-01-273-1228	PM80	GM, AND LAUNCHER SURFACE (DRAGON)

HD		QUANTITY		NEW	NEW/QD	MCE
1.1	E	2 Plts	40 ea	74	73.6	
1.2.1	E	3 Plts	60 ea	343	343.3	17.2

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	417	417	417	670	402	200*	195*

* distance for 1.2.1 items

SCL # 22 **MORTAR, 4.2 "**

SCL #22

NSN	DODIC	NOMENCLATURE
1315-01-211-8411	C697	CARTRIDGE, 4.2 HE, M329A2 W/SCRUBBER OBTURATOR
1315-00-028-5015	C706	CARTRIDGE, 4.2 ILLUM, M335
1315-00-028-5020	C708	CTG, 4.2IN SMOKE WP OR PWP M2
1390-01-202-1710	N464	FUZE, PROX M732
1390-00-187-5392	N335	FUZE, PD, M557 W/BOOSTER

HD		QUANTITY		NEW	NEW/QD	MCE
1.1	E	6 Plts	576 Rds	3815	3815.3	
1.2.1	G	1 Plts	40 Rds	166	166.1	24.9
1.2.1	H	1 Plts	40 Rds	377	376.9	56.5
1.2.2	D	1 Plts	576 Fzs	7	7.5	0.0
1.1	B	1 Plts	576 Fzs	17	17.3	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	4383	4376	4376	1250	750	200	344

* distance for 1.2.1 items

SCL # 23 **ARTILLERY, 155mm DPICM**

SCL #23

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1305-00-028-6490	A576	CTG .50 CAL API & API-T	1.4	G	1 Plts	5040 Rds	169	0.0	
1320-00-143-6847	D533	CHARGE, PROPELLING 155MM WHITE BAG M119	1.3	C	4 Plts	120 Chgs	2510	2509.9	
1320-00-028-4878	D541	CHARGE, PROPELLING 155MM M4	1.3	C	2 Plts	60 Chgs	815	815.2	
1320-00-872-3164	D563	PROJECTILE, 155MM, M483, M483A1 ON WOOD PALLET N	N 1.1	D	21 Plts	168 Rds	1000	1000.5	
1390-01-282-6038	N289	FUZE, ELECTRONIC TIME	1.4	S	12 Cntrs	192 Fzs	0	0.0	
1390-00-892-4202	N523	PRIMER, PERC M82	1.4	G	1 Bx	500 ea	2	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	4497	4326	4326	1250	750	118	293

SCL # 24 **ARTILLERY, ATACMS**

SCL #24

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1427-01-274-3904	PL81	TACMS MISSLE/LAUNCH POD XM39	1.1	E	4 ea	4 ea	7400	1640.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	7400	1640	1640	1250	750	130	212

SCL # 25 **AVIATION, AH-64**

SCL #25

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1305-01-082-8986	A965	CARTRIDGE 25.4MM DECOY M839	1.4	S	3 Plts	300 ea	0	0.0	
1305-01-155-3197	B130	CARTRIDGE 30MM M789 HEDP RH LINKED	1.2.2	E	4 Plts	62912 Rds	11192	3699.2	0.0
1340-01-108-8851	H163	ROCKET, 2.75 IN HE W/WHD M151 (HYDRA)	1.1	E	1 Plts	60 Rkts	566	566.5	
1340-01-108-8851	H163	ROCKET, 2.75 IN HE W/WHD M151 (HYDRA)	1.1	E	1 lt Plt	20 Rkts	189	188.8	
1340-01-223-9187	H464	ROCKET, 2.75 IN MPSM W/WHD M229 (HYDRA-70)	1.2.1	E	1 Plts	60 Rkts	552	552.4	110.5
1340-01-223-9187	H464	ROCKET, 2.75 IN MPSM W/WHD M229 (HYDRA-70)	1.2.1	E	1 lt Plt	20 Rkts	184	184.1	110.5
1370-01-048-2138	L410	FLARE, ACFT COUNTERMEASURE IR M206	1.3	G	3 Cntrs	300 ea	85	84.0	
1377-01-049-6365	MD73	CTG, IMPULSE M976	1.4	S	2 Cntrs	4320 ea	3	0.0	
1410-01-126-4662	PA79	GM, SURF ATTCKK AGM-114A REDUCD SMK (HELLFIRE)	1.1	E	3 Plts	27 Msls	935	381.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	13707	5656	5656	1250	750	300*	321

SCL # 26 **AVIATION, AH-1**

SCL #26

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1305-01-155-3197	B130	CARTRIDGE 30MM M789 HEDP RH LINKED	1.2.2	E	4 Plts	6912 Rds	1230	406.4	38.4
1340-00-689-4075	H826	ROCKET, 2.75 IN HEDP W/WHD M247	1.1	E	3 lt Plts	60 Rkts	504	504.0	
1340-01-108-8851	H163	ROCKET, 2.75 IN HE W/WHD M151 (HYDRA)	1.1	E	1 Plt	60 Rkts	566	566.5	
1340-01-223-9187	H464	ROCKET, 2.75 IN MPSM W/WHD M229 (HYDRA-70)	1.2.1	E	1 Plt	60 Rkts	552	552.4	110.5
1410-01-126-4662	PA79	GM, SURF ATTCKK AGM-114A REDUCD SMK (HELLFIRE)	1.1	E	3 Plts	27 Msls	935	381.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	3787	2410	2410	1250	750	300*	326

SCL # 27 **AVIATION, AH-1**

SCL #27

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1305-00-143-7034	A653	CARTRIDGE 20MM HEI AND TP-T M56A3/M220 (4/1)	1.2.2	E	4 PLts	9600 Rds	1094	229.3	0.0
1305-01-082-8986	A965	CARTRIDGE 25.4MM DECOY M839	1.4	S	3 Bxs	72 Rds	0	0.0	
1340-00-912-4548	H519	ROCKET, 2.75 IN SMK W/WHD M156	1.2.1	H	9 Bxs	46 Rkts	397	396.8	103.5
1340-01-108-8851	H163	ROCKET, 2.75 IN HE W/WHD M151 (HYDRA)	1.1	E	1 Plt	60 Rkts	566	566.5	
1340-00-026-1730	H180	ROCKET, 2.75 FLARE W/M275 WHD AND MK 40 MTR	1.3	G	1 lt Plt	36 Rkts	416	415.8	
1340-01-223-9187	H464	ROCKET, 2.75 IN MPSM W/WHD M229 (HYDRA-70)	1.2.1	E	1 Plt	60 Rkts	552	552.4	110.5
1370-01-048-2138	L410	FLARE, ACFT COUNTERMEASURE IR M206	1.3	G	3 Cntrs	300 Flrs	85	84.0	
1377-01-049-6365	MD73	CTG, IMPULSE M976	1.4	S	2 Bxs	4320 Ctgs	3	0.0	
1410-01-322-5333	PV18	GM, SURF ATTACK BGM-71F(TOW2B)	1.1	E	3 Pllts	36 Msls	487	486.8	
1410-01-322-5333	PV18	GM, SURF ATTACK BGM-71F(TOW2B)	1.1	E	2 lt Plts	6 Msls	81	81.1	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	3682	2813	2813	1250	750	300*	334*

* distance for 1.2.1 items

SCL # 28 ENGINEER, CEV/165mm

SCL #28

NSN	DODIC	NOMENCLATURE	HD			QUANTITY	NEW	NEW/QD	MCE
1305-00-449-8055	A131	CARTRIDGE 7.62MM	1.4	S	1 Plts	28800 Rds	227	0.0	
1305-00-028-6466	A576	CTG .50 CAL API M8 API-T M20	1.4	G	2 Plts	20160 Rds	677	0.0	
1305-00-752-7891	A589	CTG .50 CAL API & API-T	1.4	G	1 Plts	8160 Rds	851	0.0	
1320-00-555-5126	D570	CARTRIDGE, 165MM, HEP, M123A1	1.1	F	5 Plts	125 Ctgs	4622	4769.9	
1330-01-171-8869	G826	GRENADE,LAUNCHER,SMOKE,IR SCREENING,M76	1.2.2	G	1 Plts	768 ea	59	59.1	0.0

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	6437	4829	4829	1250	750	186	304

SCL # 29 ENGINEER, MOBILITY

SCL #29

NSN	DODIC	NOMENCLATURE	HD			QUANTITY	NEW	NEW/QD	MCE
1375-00-724-7040	M023	CHG, DEMO BLOCK M112 1 1/4 LB COMP C-4	1.1	D	6 Bxs	90 Chgs	113	112.5	
1375-00-926-1948	M028	DEMO KIT, BANGALORE TORP M1A2	1.1	D	1 Plt	8 ea	858	857.6	
1375-01-192-9174	M130	BLASTING CAP, M6	1.1	B	1 Cntrs	180 ea	1	0.5	
1375-01-315-1335	M131	CAP BLASTING NON-ELEC M7 (Improved Packaging)	1.1	B	4 Cntrs	160 ea	0	0.4	
1375-00-088-6691	M421	CHG, DEMO SHAPED M3 SERIES 40 LB	1.1	D	1 Plt	24 Chgs	720	720.0	
1375-00-204-0851	M456	CORD, DET, PETN TYPE 1 CL E (NEW=1000 ft)	1.1	D	1 3 ea 1000 ft	3000 ft	21	21.0	
1375-00-028-5246	M670	FUZE, Blasting, Time M700	1.4	S	1 8 ea 500 ft	4000 ft	11	0.0	
1375-00-926-3985	M757	CHG, ASSY DEMO M183 COMP C-4 8X2 1/2 LB	1.1	D	18 Bxs	36 Chgs	720	720.0	
1375-00-529-9032	M766	IGNITER, M2/M60 F/TIME BLASTING FUZE	1.4	S	2 Bxs	500 ea	0	0.0	
1375-01-133-4189	M913	CHG, DEMO HE LINEAR M58A3 (MICLIC)	1.1	D	3 Plts	3 ea	5250	5250.0	
1340-00-187-5104	J143	ROCKET MOTOR, 5 IN MK22 MOD 2 (FOR LINEAR DEMO)	1.3	C	3 Cntrs	3 Rkts	129	129.3	
1365-00-598-5220	K867	SMOKE POT, FLOATING HC M4A2	1.4	G	2 Plts	54 Pots	1485	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	9307	7811	7811	1250	750	218	357

SCL # 30 ENGINEER, DEMO

SCL #30

NSN	DODIC	NOMENCLATURE	HD			QUANTITY	NEW	NEW/QD	MCE
1375-00-724-7040	M023	CHG, DEMO BLOCK M112 1 1/4 LB COMP C-4	1.1	D	2 Plt	2160 Chgs	2700	2700.0	
1375-00-728-5941	M024	CHG, DEMO BLOCK M118 2LB PETN	1.1	D	2 Plt	960 Chgs	1920	1920.0	
1375-00-028-5142	M032	CHG, DEMO BLOCK TNT 1 LB	1.1	D	1 Plt	1152 Chgs	1152	1152.0	
1375-01-250-6029	M039	CHG, DEMO BLOCL 40 LB CRATERING	1.1	D	1 Plt	50 Chgs	7022	2021.5	
1375-00-028-5224	M130	BLASTING CAP, ELEC. J2	1.1	B	1 Bx	500 ea	1	1.0	
1375-00-028-5228	M131	CAP BLASTING NON-ELEC M7	1.1	B	1 Bx	500 ea	1	1.0	
1375-00-028-5171	M241	DESTRUCTOR, Expl UNIVERSAL M10	1.1	D	1 Cntr	50 ea	14	14.3	
1375-00-028-5237	M420	CHG, DEMO SHAPED M2 SERIES 15 LB	1.1	D	1 Plt	60 Chgs	690	690.0	
1375-00-088-6691	M421	CHG, DEMO SHAPED M3 SERIES 40 LB	1.1	D	1 Plt	24 Chgs	720	720.0	
1375-00-204-0851	M456	CORD, DET, PETN TYPE 1 CL E (NEW=1000 ft)	1.1	D	3 Bx 3 rolls	9000 ft	63	63.0	
1375-00-028-5246	M670	FUZE, Blasting, Time M700	1.4	S	1 9-500 ft	4500 ft	12	0.0	
1375-00-926-3985	M757	CHG, ASSY DEMO M183 COMP C-4 8X2 1/2 LB	1.1	D	1 Plt	72 Chgs	1440	1440.0	
1375-00-529-9032	M766	IGNITER, M2/M60 F/TIME BLASTING FUZE	1.4	S	2 Bxs	500 ea	0	0.0	
1375-00-148-7159	M965	CHG, DEMO CRATERING M180	1.1	E	3 Plts	9 Chgs	505	505.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	16240	11228	11228	1250	750	246	403

SCL # 31 ENGINEER, MINES

SCL #31

NSN	DODIC	NOMENCLATURE	HD			QUANTITY	NEW	NEW/QD	MCE
1345-01-228-8477	K068	FUZE, M624 F/MINE AT M15	1.4	S	1 Plt	480 Fzs	2	0.0	
1345-00-028-5131	K092	MINE, APERS M16 SERIES BOUNDING	1.2.2	D	1 Plt	400 ea	516	515.8	0.0
1345-01-142-3441	K180	MINE, AT HEAVY M15	1.1	D	3 Plt	90 ea	2052	2052.0	
1345-00-729-4263	K181	MINE AT HEAVY M21	1.1	D	6 Plt	144 ea	1555	1555.2	
1375-00-580-1392	M630	DETONATOR, FLASH, M86, NON-PROP PACK	1.4	B	3 Bxs	400 ea	0	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	4125	4123	4123	1250	750	176	289

SCL # 32 **ARTILLERY, ADAMS-L**

NSN	DODIC	NOMENCLATURE
1320-00-143-6847	D533	CHARGE, PROPELLING 155MM WHITE BAG M119
1320-00-143-6847	D533	CHARGE, PROPELLING 155MM WHITE BAG M119
1320-00-434-8856	D501	PROJECTILE 155MM HE M692
1390-01-247-4013	N285	FUZE, MTSQ M577/577A1 W/O BOOSTER
1390-00-892-4202	N523	PRIMER, PERC M82

SCL #32

HD		QUANTITY		NEW	NEW/QD	MCE
1.3	C	4 Plts	120 Chgs	2510	2509.9	
1.3	C	3 lt plts	54 Chgs	1129	1129.5	
1.2.1	D	21 Plts	168 Rds	317	317.3	45.3
1.4	D	1 lt Plt	192 ea	0	0.0	
1.4	G	1 Bx	500 ea	2	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.2.1	3958	317	45	492	295	200	177

SCL # 33 **ARTILLERY, ADAMS-S**

NSN	DODIC	NOMENCLATURE
1320-00-143-6847	D533	CHARGE, PROPELLING 155MM WHITE BAG M119
1320-00-143-6847	D533	CHARGE, PROPELLING 155MM WHITE BAG M119
1320-00-434-8861	D502	PROJECTILE 155MM HE M731
1390-01-247-4013	N285	FUZE, MTSQ M577/577A1 W/O BOOSTER
1390-00-892-4202	N523	PRIMER, PERC M82

SCL #33

HD		QUANTITY		NEW	NEW/QD	MCE
1.3	C	4 Plts	174 Chgs	3639	3639.4	
1.3	C	3 lt plts	54 Chgs	1129	1129.5	
1.2.1	D	21 Plts	168 Rds	317	317.3	45.3
1.4	D	1 lt Plt	192 ea	0	0.0	
1.4	G	1 Bx	500 ea	2	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.2.1	5088	317	45	492	295	200	177

SCL # 34 **ARTILLERY, RAAMS-S**

NSN	DODIC	NOMENCLATURE
1320-00-143-6847	D533	CHARGE, PROPELLING 155MM WHITE BAG M119
1320-00-143-6847	D533	CHARGE, PROPELLING 155MM WHITE BAG M119
1320-01-150-7857	D514	PROJ 155 M741A1 (OLD BASE)
1390-01-247-4013	N285	FUZE, MTSQ M577/577A1 W/O BOOSTER
1390-00-892-4202	N523	PRIMER, PERC M82

SCL #34

HD		QUANTITY		NEW	NEW/QD	MCE
1.3	C	4 Plts	174 Chgs	3639	3639.4	
1.3	C	3 lt plts	54 Chgs	1129	1129.5	
1.1	D	21 Plts	168 Rds	1973	1972.7	
1.4	D	1 lt Plt	192 ea	0	0.0	
1.4	G	1 Bx	500 ea	2	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	6743	6742	6742	1250	750	208	340

SCL # 35 **ARTILLERY, RAAM-L**

NSN	DODIC	NOMENCLATURE
1320-00-143-6847	D533	CHARGE, PROPELLING 155MM WHITE BAG M119
1320-00-143-6847	D533	CHARGE, PROPELLING 155MM WHITE BAG M119
1320-01-150-7857	D514	PROJ 155 M741A1 (OLD BASE)
1390-01-247-4013	N285	FUZE, MTSQ M577/577A1 W/O BOOSTER
1390-00-892-4202	N523	PRIMER, PERC M82

SCL #35

HD		QUANTITY		NEW	NEW/QD	MCE
1.3	C	4 Plts	174 Chgs	3639	3639.4	
1.3	C	3 lt plts	54 Chgs	1129	1129.5	
1.1	D	21 Plts	168 Rds	1973	1972.7	
1.4	D	1 lt Plt	192 ea	0	0.0	
1.4	G	1 Bx	500 ea	2	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	6743	6742	6742	1250	750	208	340

SCL # 36 **ARTILLERY, RAP**

NSN	DODIC	NOMENCLATURE
1320-01-202-8938	D532*	CHG PROP 155MM
1320-01-202-8938	D532*	CHG PROP 155MM
1320-01-047-6009	D579	PROJECTILE, 155MM, HERA, M549A1
1390-01-247-4012	N286	FUZE, MTSQ M582A1 WRBND BX
1390-01-132-7481	N340	FUZE, PD M739
1390-00-892-4202	N523	PRIMER, PERC M82

SCL #36

HD		QUANTITY		NEW	NEW/QD	MCE
1.3	C	4 Plts	96 Chgs	2880	2880.0	
1.3	C	4 lt plts	72 Chgs	2160	2160.0	
1.1	D	21 Plts	168 Rds	3666	3666.5	
1.2.2	D	2 Bxs	32 ea	2	1.7	0.0
1.2.2	D	9 Bxs	144 ea	7	6.9	0.0
1.4	G	1 Bx	500 ea	2	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	8717	8715	8715	1250	750	227	371

SCL # 37 **ARTILLERY, HE**

SCL #37

HSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1320-00-143-6847	D533	CHARGE, PROPELLING 155MM WHITE BAG M119	1.3	C	2 lt plts	36 Chgs	753	753.0	
1320-00-143-6847	D533	CHARGE, PROPELLING 155MM WHITE BAG M119	1.3	C	2 lt plts	24 Chgs	502	502.0	
1320-00-028-4889	D544	PROJECTILE, 155MM HE M107	1.1	D	24 Plts	192 Rds	2861	2860.8	
1320-00-028-4878	D541	CHARGE, PROPELLING 155MM M4	1.3	C	3 Plts	150 Chgs	2038	2038.1	
1390-01-132-7481	N340	FUZE, PD M739	1.2.2	D	1 Plts	576 ea	28	27.6	0.0
1390-01-020-0096	N464	FUZE, PROX M732	1.2.2	D	1 Plts	576 ea	7	7.4	0.0
1390-00-892-4202	N523	PRIMER, PERC M82	1.4	G	1 Bx	500 ea	2	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	6190	6189	6189	1490	894	202	331

SCL # 38 **ARTILLERY, ILLUM**

SCL #38

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1320-00-143-6847	D533	CHARGE, PROPELLING 155MM WHITE BAG M119	1.3	C	2 lt plts	36 Chgs	753	753.0	
1320-00-143-6847	D533	CHARGE, PROPELLING 155MM WHITE BAG M119	1.3	C	2 lt plts	24 Chgs	502	502.0	
1320-00-926-9388	D505	PROJECTILE, 155MM ILLUM M485A1	1.3	G	224 Plts	192 Rds	1186	1185.7	
1320-00-028-4878	D541	CHARGE, PROPELLING 155MM M4	1.3	C	3 Plts	150 Chgs	2038	2038.1	
1390-00-805-0692	N285	FUZE, MTSQ M577/577A1 W/O BOOSTER	1.4	D	2 Plts	1152 ea	2	0.0	
1390-00-892-4202	N523	PRIMER, PERC M82	1.4	G	1 Bx	500 ea	2	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.3	4482	4479	0	132	132	82	82

SCL # 39 **ARTILLERY, COPPERHEAD**

SCL #39

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1320-01-077-4279	D510	PROJECTILE,155MM,M712	1.1	D	10 Plts	60 Rds	886	885.5	
1320-00-143-6847	D533	CHARGE, PROPELLING 155MM WHITE BAG M119	1.3	C	1 Plt	30 Chgs	627	627.5	
1320-00-028-4878	D541	CHARGE, PROPELLING 155MM M4	1.3	C	1 Plt	50 Chgs	679	679.4	
1390-00-892-4202	N523	PRIMER, PERC M82	1.4	G	1 Bx	500 ea	2	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	2194	2192	2192	1250	750	143	234

SCL # 40 **AIR DEFENSE, STINGER**

SCL #40

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1425-01-325-0695	PJ12	GM, INTER-AREAL,, FIM-92D (STINGER-RMP-SDAM)	1.1	E	12 Plts	108 ea	1142	94.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	1142	94	94	1250	750	50	82

SCL # 41 **MORTAR, 120mm**

SCL #41

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1315-01-335-5016	C379	CTG 120MM HE M934 W/FUZE MO M734 IN PA154 MTL CT	1.1	E	8 Plts	384 Rds	3040	3040.4	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	3040	3040	3040	1250	750	159	261

SCL # 42 **MORTAR, 81mm**

SCL #42

NSN	DODIC	NOMENCLATURE	HD		QUANTITY		NEW	NEW/QD	MCE
1315-01-353-7618	C868*	CARTRIDGE, 81MM, HE, M821A1, W/FUZE M734	1.1	E	6 Plts	756 Rds	1771	1770.6	
1315-01-289-9789	C871	CTG, 81MM, ILLUM, M853A1 W/FUZE M772 IN WOOD BOX	1.2.1	G	1 Plts	63 Rds	118	117.7	16.8
1315-01-199-8688	C870	CARTRIDGE, 81MM, M819, RP, W/FUZE, MTSQ, M772	1.3	G	1 Plts	90 Rds	29	29.3	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	1918	1918	1918	1250	750	200*	294*

* distance for 1.2.1 items

SCL # 43 **MORTAR, 60mm**

NSN	DODIC	NOMENCLATURE
1310-01-149-3185	B643	CARTRIDGE 60MM HE M888 W/FUZE M935
1310-01-236-1354	B646	CARTRIDGE 60MM SMOKE WP MARKING XM722
1310-01-258-8689	B647	CARTRIDGE 60MM ILLUM M721

SCL #43

HD		QUANTITY		NEW	NEW/QD	MCE
1.2.2	E	6 Plts	2593 Rds	2335	2334.7	0.0
1.3	H	1 Plts	288 Rds	30	30.5	
1.2.2	G	1 Plts	384 Rds	261	261.1	0.0

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.2.2	2626	2596	2596	110	110	69	69

SCL # 44 **105mm Smoke(WP)**

NSN	DODIC	NOMENCLATURE
1315-00-470-5368	C454	CTG, 105MM SMOKE WP M60
1390-01-132-7481	N340	FUZE, PD M739

SCL #44

HD		QUANTITY		NEW	NEW/QD	MCE
1.2.1	H	8 Plts	320 Rds	2115	2115.2	39.7
1.2.2	D	1 lt Plt	320 Fz	15	15.4	2.3

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.2.1	2131	2115	40	833	500	200	299.88

SCL # 45 **105MM, ILLUM**

NSN	DODIC	NOMENCLATURE
1315-01-300-2748	C449	CARTRIDGE, 105MM, ILLUMINATING, M314A3
1390-01-158-8193	N286	FUZE, MTSQ M582A1

SCL #45

HD		QUANTITY		NEW	NEW/QD	MCE
1.2.1	G	8 Plts	384 Rds	1959	1958.6	30.6
1.2.2	D	1 Plts	394 Fz	21	20.6	2.5

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.2.1	1979	1959	30.6	820	492	200	295.2

SCL # 46 **105MM, HE**

NSN	DODIC	NOMENCLATURE
1315-00-028-4861	C445	CARTRIDGE, 105MM HE M1 W/O FUZE
1390-01-132-7481	N340	FUZE, PD M739
1390-01-020-0096	N464	FUZE, PROX M732

SCL #46

HD		QUANTITY		NEW	NEW/QD	MCE
1.2.1	E	8 Plt	360 Rds	2798	2798.3	46.6
1.2.2	D	1 lt Plt	192 Fzs	9	9.2	0.0
1.2.2	D	1 lt Plt	192 Fzs	2	2.5	0.0

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.2.1	2810	2798	47	881	529	200	317

SCL # 47 **105MM, HE M760**

NSN	DODIC	NOMENCLATURE
1315-01-189-7764	C473	CARTRIDGE, 105MM, HE, M760
1390-01-132-7481	N340	FUZE, PD M739
1390-01-202-1710	N464	FUZE, PROX M732

SCL #47

HD		QUANTITY		NEW	NEW/QD	MCE
1.2.1	E	8 Plts	384 Rds	3529	3529.0	27.6
1.2.2	D	1 lt Plt	192 Fzs	9	9.2	0.0
1.2.2	D	1 lt Plt	192 Fzs	2	2.5	0.0

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.2.1	3541	3529	28	1000	600	200	360

SCL # 48 **105MM, HERA**

NSN	DODIC	NOMENCLATURE
1315-01-250-2857	C546	CARTRIDGE, 105MM, M913, HERA, IN PA117
1390-01-132-7481	N340	FUZE, PD M739
1390-01-020-0096	N464	FUZE, PROX M732

SCL #48

HD		QUANTITY		NEW	NEW/QD	MCE
1.2.1	E	10 Plts	300 Rds	3855	3855.2	38.6
1.2.2	D	1 Plts	576 Fzs	28	27.6	0.0
1.2.2	D	1 Plts	576 Fzs	7	7.4	0.0

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.2.1	3890	3855	39	935	561	200	337

SCL # 49 **KIOWA WARRIOR OH-58D** SCL #49

NSN	DODIC	NOMENCLATURE	HD		QUANTITY	NEW	NEW/QD	MCE
1410-01-126-4662	PA79	GM, SURF ATTCKK AGM-114A REDUCD SMK (HELLFIRE)	1.1	E	27 ea	935	381.0	
1425-01-325-0695	PJ12	GM, INTER-AREAL,, FIM-92D (STINGER-RMP-SDAM)	1.1	E	18 ea	190	15.7	
1305-01-082-8986	A965	CARTRIDGE 25.4MM DECOY M839	1.4	S	300 ea	0	0.0	
1370-01-048-2138	L410	FLARE, ACFT COUNTERMEASURE IR M206	1.3	G	1500 ea	426	420.0	
1377-01-049-6365	MD73	CTG, IMPULSE M976	1.4	S	21600 ea	17	0.0	

LD HD	NEW	NEWQD	MCE	IBD	PTR	IMD	ILD
1.1	1568	817	817	1250	750	103	168

Appendix B
British Army Configured Loads

UK AMMO LOAD COMPONENTS INFANTRY SUB-UNIT (ARMOURED)							
CODE	DESIGNATION	HCC	QUANTITY	PALLS	BOXES	TONNE	NEQ KG
11903	RDS 5.56MM BALL BND SA80	1.4S	8540	0	10	0.14	13
11906	RD 5.56MM 4B/1T BTD SA80	1.4S	22167	0	25	0.37	33
12002	RD 7.62MM BALL BDR L2AZ	1.4S	93	0	1	0.01	0
12007	RD 7.62MM 4B/1T BELTED L	1.4S	18667	0	24	0.76	56
12009	RD 7.62MM 1B/1T BELTED L	1.4S	3500	0	5	0.14	11
12201	RD 9MM BALL CARTON MK 2Z	1.4S	5	0	1	0.01	0
12701	RKT HANDFIRED PARA ILLUM	1.22G	36	0	1	0.02	4
12802	SIG KIT PYRO PSTL 16MM W	1.4G	25	0	1	0.01	1
12803	SIG KIT PYRO PSTL 16MM G	1.4G	22	0	1	0.01	1
12804	SIG KIT PYRO PSTL 16MM R	1.4G	22	0	1	0.01	1
13201	FLARE TRIPWARE MK 3/1	1.34G	11	0	1	0.03	2
16578	GREN HAND SMK RED	1.34G	11	0	2	0.01	2
16579	GREN HAND ORANGE	1.34G	11	0	2	0.01	2
17401	GREN HAND HE L2A1 W/F L2	1.22D	317	0	32	0.24	55
18102	MORTAR BOMB 51MM HE L12A	1.21E	61	0	7	0.09	15
18120	MORTAR BOMB 51MM ILLUM L	1.22G	88	0	15	0.12	26
18122	MORTAR BOMB 51MM SMOKE	1.4G	61	0	11	0.08	34
18701	RKT 94MM HEAT (LAW 80)	1.1E	33	1	9	1.11	50
21802	GREN NO 80 SMK WP MK1 HA	1.22H	38	0	3	0.03	12
22202	GREN DSCHGR SMK SCR L8A4	1.4G	348	0	70	0.50	126
24501	ROUND 30MM AFV HE L8A2	1.22E	468	0	32	0.60	90
24510	ROUND 30MM AFV AP	1.4C	732	0	49	0.95	113
	TOTALS			1	303	5.25	647

UK AMMO LOAD COMPONENTS LIGHT GUN SUB-UNIT							
CODE	DESIGNATION	HCC	QUANTITY	PALLS	BOXES	TONNE	NEQ KG
11903	RDS 5.56MM BALL BND SA80	1.4S	14350	0	16	0.24	22
12003	RD 7.62 BALL CTN L2A2	1.4S	933	0	2	0.03	3
12005	RD 7.62MM TRACER CTN L5A	1.4S	233	0	1	0.01	1
12007	RD 7.62MM 4B/1T BELTED L	1.4S	3500	0	5	0.13	7
12009	RD 7.62MM 1B/1T BELTED L	1.4S	1167	0	2	0.04	4
12201	RD 9MM BALL CARTON MK 2Z	1.4S	7	0	1	0.01	0
12701	RKT HANDFIRED PARA ILLUM	1.22G	50	0	2	0.03	6
12802	SIG KIT PYRO PSTL 16MM W	1.4G	6	0	1	0.01	0
12803	SIG KIT PYRO PSTL 16MM G	1.4G	6	0	1	0.01	0
12804	SIG KIT PYRO PSTL 16MM R	1.4G	6	0	1	0.01	0
13201	FLARE TRIPWARE MK 3/1	1.34G	11	0	1	0.03	2
17401	GREN HAND HE L2A1 W/F L2	1.22D	36	0	4	0.02	6
18701	RKT 94MM HEAT (LAW 80)	1.1E	7	0	7	0.23	11
22202	GREN DSCHGR SMK SCR L8A4	1.4G	96	0	20	0.14	35
35410	SHELL 105 FD MK2 HE TNT	1.1D	783	10	32	16.56	2028
35430	SHELL 105 FD MKZ SMK SCR	1.22G	72	1	0	1.56	176
35440	SHELL 105MM FD ILUM NXRY	1.22G	27	0	14	0.56	48
35456	RING SPOILER L1A1	N/A	9	0	1	0.01	0
35464	SHELL 105MM FD RED SMK	1.22G	9	0	5	0.19	12
35465	SHELL 105 FD ORANGE SMK	1.22G	225	3	5	4.79	311
35470	CART 105 FD MKZ NORMAL L	1.33C	45	0	23	0.58	110
35475	CART 105 FD MKZ SUPER L3	1.33C	27	0	14	0.37	93
37461	FUZE MR	1.4D	153	0	13	0.29	1
50404	SAFETY FUZE L1A2 (METRIC)	1.4S	100	0	2	0.01	1
50603	CORD DETONATING (METRIC)	1.1D	1200	0	4	0.09	11
51010	DET DEM NON ELEC	1.1B	50	0	1	0.01	0
51301	FIRING DEVICE DEM GRIP	1.4S	15	0	1	0.01	0
52412	CHGE DEM 8OZ CART NO 4 P	1.1D	350	0	9	0.22	169
58804	COUPLER KIT DEMO (INERT)	N/A	75	0	5	0.03	0
	TOTALS			14	193	26.22	3047

UK AMMO LOAD COMPONENTS MEDIUM GUN SUB-UNIT							
CODE	DESIGNATION	HCC	QUANTITY	PALLS	BOXES	TONNE	NEQ KG
11903	RDS 5.56MM BALL BND SA80	1.4S	14350	0	16	0.24	22
12003	RD 7.62 BALL CTN L2A2	1.4S	933	0	2	0.03	3
12005	RD 7.62MM TRACER CTN L5A	1.4S	233	0	1	0.01	1
12007	RD 7.62MM 4B/1T BELTED L	1.4S	12833	0	17	0.52	11
12009	RD 7.62MM 1B/1T BELTED L	1.4S	1167	0	2	0.04	4
12201	RD 9MM BALL CARTON MK 2Z	1.4S	7	0	1	0.01	0
12701	RKT HANDFIRED PARA ILLUM	1.22G	50	0	2	0.03	6
12802	SIG KIT PYRO PSTL 16MM W	1.4G	6	0	1	0.01	0
12803	SIG KIT PYRO PSTL 16MM G	1.4G	6	0	1	0.01	0
12804	SIG KIT PYRO PSTL 16MM R	1.4G	6	0	1	0.01	0
13201	FLARE TRIPWARE MK 3/1	1.34G	11	0	1	0.03	2
17401	GREN HAND HE L2A1 W/F L2	1.22D	36	0	4	0.02	6
18701	RKT 94MM HEAT (LAW 80)	1.1E	7	0	7	0.23	11
22202	GREN DSCHGR SMK SCR L8A4	1.4G	96	0	20	0.14	35
36075	CHGE PROP 155MM CHGE 8	1.33C	424	8	24	6.65	3742
36102	SHELL 155MM L15 HE	1.1D	2552	75	1	118.51	29353
36125	CHGE PROP 155MM HOW CHGE	1.33C	2600	152	1	95.16	19630
36126	CHGE PROP 155MM HOW CHGE	1.33C	1276	37	1	34.19	15746
36140	SHELL 15S SMK PLGD	1.22G	600	75	0	33.00	3600
36150	SHELL 155 ILLUM PLGD	1.22G	300	37	4	16.53	1080
36170	SHELL 155MM HQW HE M483	1.1D	848	49	1	53.84	2493
37425	FUZE NOSE PERC L106	1.4D	128	0	6	0.24	1
37437	FUZE NOSE ELECTRONIC TIM	1.4G	1748	3	26	3.21	5
37461	FUZE MR	1.4D	2552	5	13	4.89	13
37861	PRIMER DM 191	1.4G	4816	0	32	0.24	6
50404	SAFETY FUZE L1A2 (METRIC)	1.4S	100	0	2	0.01	1
50603	CORD DETONATING (METRIC)	1.1D	1200	0	4	0.09	11
51010	DET DEM NON ELEC	1.1B	50	0	1	0.01	0
51301	FIRING DEVICE DEM GRIP	1.4S	15	0	1	0.01	0
52412	CHGE DEM 8OZ CART NO 4 P	1.1D	350	0	9	0.22	169
58804	COUPLER KIT DEMO (INERT)	N/A	75	0	5	0.03	0
	TOTALS			441	207	368.16	75941

UK AMMO LOAD COMPONENTS ARMOURED TANK SUB-UNIT							
CODE	DESIGNATION	HCC	QUANTITY	PALLS	BOXES	TONNE	NEQ KG
11903	RDS 5.56MM BALL BND SA80	1.4S	4900	0	6	0.08	7
11906	RD 5.56MM 4B/1T BTD SA80	1.4S	3500	0	4	0.05	5
12003	RD 7.62 BALL CTN 2A2	1.4S	1867	0	4	0.06	6
12005	RD 7.62MM TRACER CTN L5A	1.4S	467	0	2	0.01	2
12007	RD 7.62MM 4B/1T BELTED L	1.4S	2334	0	3	0.09	7
12009	RD 7.62MM 1B/1T BELTED L	1.4S	28000	0	35	1.14	84
12201	RD 9MM BALL CARTON MK 2Z	1.4S	61	0	1	0.01	0
12802	SIG KIT PYRO PSTL 16MM W	1.4G	16	0	1	0.01	1
12803	SIG KIT PYRO PSTL 16MM G	1.4G	16	0	1	0.01	1
12804	SIG KIT PYRO PSTL 16MM R	1.4G	16	0	1	0.01	1
13201	FLARE TRIPWARE MK 3/1	1.34G	10	0	1	0.03	2
16576	GREN HAND SMK BLUE	1.34G	5	0	1	0.01	1
16577	GREN HAND SMK GREEN	1.34G	5	0	1	0.01	1
16578	GREN HAND SMK RED	1.34G	5	0	1	0.01	1
16579	GREN HAND ORANGE	1.34G	5	0	1	0.01	1
17401	GREN HAND HE L2A1 W/F L2	1.22D	132	0	14	0.10	23
18701	RKT 94MM HEAT (LAW 80)	1.1E	8	0	8	0.27	12
22202	GREN DSCHGR SMK SCR L8A4	1.4G	516	0	104	0.75	187
27012	SHELL 120MM SMK WP	1.22H	38	0	19	1.22	164
27025	SHELL 120MM TK HESH W/CH	1.1S	126	3	12	4.25	824
27040	SHOT 120MM TK AFFSDS L23	1.33C	256	7	25	8.53	1997
27060	CHGE PROP 120MM TANK HES	1.33C	164	2	11	1.52	507
27067	CHGE PROP 120MM TK L8A1	1.33C	256	8	16	5.22	2288
28206	TUBE VENT ELEC .625IN L3	1.4G	460	0	5	0.09	3
	TOTALS			20	277	23.49	6125

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14. ABSTRACT

This study was conducted to (a) develop realistic estimates of the safety hazard ranges (i.e., quantity distances, or "QD's") for accidental explosions of ammunition in ISO shipping containers, and (b) investigate methods for reducing QD's for ammunition containers at temporary storage sites. The QD's of interest are the Inhabited Building Distance (IBD), Public Traffic Route distance (PTR), and Intermagazine Distance (IMD). QD's were established for the U.S. Army's 49 current Strategic Configured Loads (SCL's), as examples of mixed ammo loads. Phase 1 of the study was an analytical effort, in which QD's were calculated using accepted analytical methods. The calculated IBD's and PTR's for the 49 SCL's generally ranged from 30 to 80 percent less than those derived from the current U.S. and NATO safety standards. IMD's were similarly reduced, ranging from about 50 to 75 percent less than those indicated by current standards.

Phase 2 was a test program to verify the reduction in safe separation distance (IMD's) between ammunition containers, and to evaluate the effectiveness of sand-filled barricades in reducing IMD's to 20 ft (6 m) or less. Among other findings, the tests proved that a sand barrier as thin as 18 in. (46 cm) will stop or slow fragments enough to prevent propagation between ISO containers.

15. SUBJECT TERMS

Ammunition	ISO containers
Explosives safety	Quantity distances

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